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The coal deposits of Batan Island

Warren DuPré Smith, Philippines. Mining Bureau

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THE COAL DEPOSITS OF BATAN ISLAND

WITH NOTES ON THE GENERAL AND ECONOMIC GEOLOGY OF THE ADJACENT REGION

BY

WARREN DU PRE SMITH

A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
UNIVERSITY OF WISCONSIN
1908

(REPRINT OF BULLETIN NO. 5 OF THE MINING BUREAU OF THE PHILIPPINE ISLANDS)

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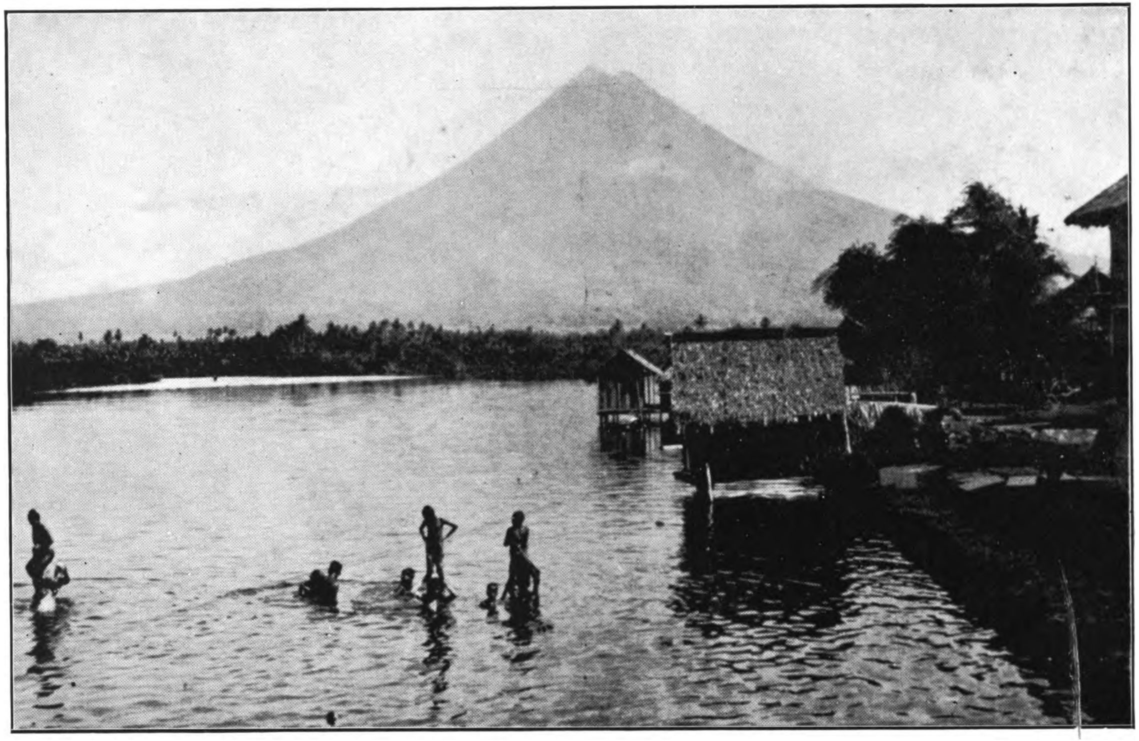

Photo by Valentine Wilson.

MAYON VOLCANO FROM LEGASPI.

BULLETIN No. 5

DEPARTMENT OF THE INTERIOR

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COAL DEPOSITS—BATAN ISLAND.

BULLETIN NO. 5, MINING BUREAU.

ERRATA.

Page.

14. Insert "fig. 2" at end of last line.

15. Insert comma and space after "south" in title of fig.

18. In table at bottom of page "pyroxenite" not "peroxinite."

19. Last word in first line of footnote 2 should read "*Igneous*."

22. Fifth line from the bottom: Insert "iron" between the words "great" and "ore."

27. In footnote: Insert "and" between words "Steinkohle" and "Eiweisskörper" and umlaut the "o" in the latter.

29. Insert "½ R." instead of "one-half rhombs" in last line.

42. Line 9 should read "above the coal beds" instead of "above in coal beds."

44. Fourth line should read "Kiushiu" instead of "Kiuskin" and "Chikubo" instead of "Chikuko."

49. Last line of next to last paragraph read "larger part" instead of "large part."

51. Read "Igorot" for "Igorots."

55. Table II, in column of costs change "$9.00" to "$4.50," as 9.00 is in Philippine currency.

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DEPARTMENT OF THE INTERIOR.
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WITH NOTES ON THE GENERAL AND ECONOMIC GEOLOGY OF THE ADJACENT REGION

BY

WARREN D. SMITH, B. S., M. A.
GEOLOGIST, MINING BUREAU

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LETTER OF TRANSMITTAL.

MANILA, P. I., *October 30, 1905.*

SIR: I have the honor to transmit herewith, with recommendation for its early publication, the material prepared by Mr. W. D. Smith, B. S., M. A., geologist, Mining Bureau, for Bulletin No. 5 of this Bureau, entitled "The Coal Deposits of Batan Island, with Notes on the General and Economic Geology of the Adjacent Region."

This is the first of a series of contributions planned to cover the economic geology of the Philippine coal fields, and the second of the general series of publications upon the economic geology of the Islands, planned by the Chief of the Mining Bureau as reorganized under Act No. 916. This, his first work in Philippine fields, is in my opinion highly creditable to Mr. Smith.

Very respectfully,

H. D. McCASKEY,
Chief of the Mining Bureau.

Hon. D. C. WORCESTER,
Secretary of the Interior, Manila.

LETTER OF SUBMITTAL.

THE MINING BUREAU,
Manila, P. I., October 12, 1905.

SIR: I have the honor herewith to submit a report on "The Coal Deposits of Batan Island, with Notes on the General and Economic Geology of the Adjacent Region."

Respectfully,

WARREN D. SMITH, ~~B. S., M. A.~~,
Geologist, Mining Bureau.

MR. H. D. McCASKEY,
Chief of the Mining Bureau, Manila.

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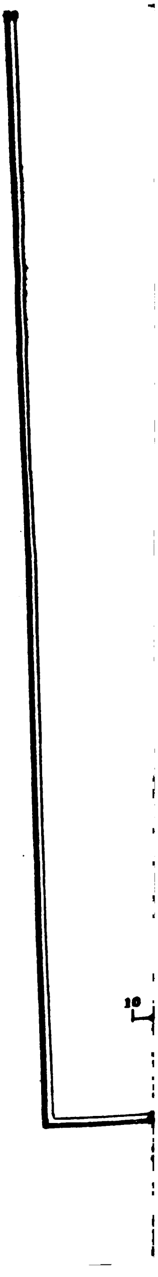

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THE COAL DEPOSITS OF BATAN ISLAND.

INTRODUCTION.

The purpose of this field work, primarily, was that of lending assistance to Lieut. H. L. Wigmore, Corps of Engineers, U. S. A., in his exploratory work on the United States military reservation on Batan Island. As the work progressed and the country was looked over it was soon seen that work of a more comprehensive nature could be taken up with considerable profit to those interested in the mineral resources, and with many features of a purely scientific interest as well.

The area covered was the entire Island of Batan, with trips around the coast and across the Islands of Rapurapu, Cacraray, and to the "mainland" in the vicinity of Sugot Bay, Mayon Volcano, and Tibi Hot Springs, for purposes of correlation and exploration.

ACKNOWLEDGMENTS.

The writer wishes to make acknowledgments at this time to the following:

The United States military authorities in the Philippine Islands, for permission to use the valuable data obtained by First Lieut. H. L. Wigmore, Corps of Engineers, U. S. A.

Lieut. H. L. Wigmore, for much assistance in the field and office and many personal courtesies.

Mr. O. H. Halvorsen, former superintendent of explorations, for much valuable data.

Dr. Lewis and Mr. Fox, of the Bureau of Government Laboratories, the former for assistance in the calorimetric work and the latter for the analyses.

Mr. A. J. Eveland, for many valuable suggestions.

Mr. Maurice Goodman, for assistance with the maps.

First-Class Private John R. Yeager, for assistance in the active field work.

METHODS OF FIELD WORK.

In a country where only the coast line and a few prominent points in the interior are accurately located; where the forest and jungle growth are so thick that these points can almost never be seen except from the sea, and a mile or two of traverse is a day's work and one of hard labor with the bolo; where the soil is so thick that outcrops are hidden—the difficulties of systematic field work are very discouraging. It was found more feasible to keep to the coast line and the streams for the most part, but at times the traverse system as employed in the Lake Superior surveys was used. Running lines through jungle and over the rough limestone full of sink holes is not suited to close pacing. Even when the highest trees were climbed on the mountains scarcely anything could be made out of the surrounding country. Therefore this report should be considered, as far as the geological part is concerned, more in the nature of a reconnoissance. Many problems in stratigraphy and paleontology have been opened up to the investigator, and these for many reasons will have to await a more opportune time for further study. Many questions we purposely leave until a more extended acquaintance with the geology of the Islands shall have been made.

GEOLOGY.

GEOGRAPHY.

GENERAL.

Batan Island, in the Province of Albay, lies slightly northeast of Legaspi about 12 miles and is bounded on the west by Cacraray Island, on the east by Rapurapu Island, is due east of Mayon Volcano, is bisected by the one hundred and twenty-fourth meridian, and lies between 13° 10′ and 13° 20′ north latitude. The island has a very irregular coast line, but its greatest east-and-west line is 13 miles long, while along its greatest north-and-south line it measures only 4¾ miles. Sixty-one and three-fourths square miles would be much too large an estimate of the area, and taking into account the numerous bays and inlets it would seem that 45 square miles would be a fair estimate.

There are no roads and only a few trails on this island; the streams are small and intermittent; the chief barrio is Batan, situated on the coast at the southeast end of the island. This barrio and a score of visitas along the coast all come under the jurisdiction of the pueblo of Rapurapu.

The island is coral girt, but happily there are breaks in the reefs so that ocean-going vessels can come close in, as at Coal Harbor, between Cacraray and Batan, within 100 yards of the shore. Launches drawing 6 to 10 feet of water can pass around three-fourths of the island but can not clear the reefs in Cacraray Passage, and at low tide it is difficult even for shallow barotos.

All these features are shown on the large scale map of the island compiled from maps of the Coast and Geodetic Survey, by the Corps of Engineers under the direction of Lieut. H. L. Wigmore and Lieutenant Markham, and by the geologist in charge of the geological survey of the district.

The best harbor facilities at Batan, and, for that matter, anywhere along the east coast of Luzon for 100 miles, are undoubtedly those afforded at Liguan on the west end of the island. Here an anchorage perfectly sheltered from any strong winds can be obtained in 17 fathoms with a mud bottom, and this within the limit to which it would be feasible to erect a dock. The average tide amounts to about 3 feet, but gets as high as 7 or 8 feet in the spring and at the time of full moon.

CLIMATE.

The climate is considered, by those who have lived there any length of time, as good as that of the most favorable spots in the Islands. During the progress of the field work there was always a breeze from the sea which made it very comfortable whenever the party was fortunate enough to be near the coast. The nights were invariably cool, a blanket being necessary most of the time. Mosquito bars may be dispensed with almost entirely. Attached is a table (Table I) showing range of temperature and rainfall, compiled from the monthly reports of the Legaspi meterological station.

VEGETATION.

At first sight Batan Island seems to be vegetation and nothing else, and when one sets out to trace outcrops he is not quickly disillusioned. From the shore or the sea scarcely an outcrop can be seen, so thick is the undergrowth. The principal trees are red narra (*Pterocarpus indica*), some of which reach a height of 150 feet; molave, doa, and bejuco on the higher ground; in swampy estuaries bacauan (*Bruguiera caryophyllaeoides*) and bacagua. On the east ridge, running from Calanaga Bay to East Point, which is underlain by volcanic rock, a few scattered jack pines—tapulao (*Pinus merkusii*)—are to be seen. With the exception of this ridge the undergrowth is exceptionally thick, requiring the continued employment of bolomen.

The red narra, which is to be found in great abundance all over the island, affords all the timber for mine timbering and buildings that will ever be required.

The most striking-looking tree encountered in these wild spots is by far the doa, which starts up from the huge buttresses to a height of 100 feet, and in some cases of nearly 150 feet. The effect produced on one as he suddenly breaks through the jungle and comes upon one of these monarchs is akin to the sensation felt when one has walked for hours through stuffy city streets and comes suddenly upon a great cathedral.

POPULATION.

For the most part the population is confined to the coast and is made up almost entirely of Bicols, a tribe which is found throughout Sorsogon, Albay, and Ambos Camarines in great numbers. These people are distributed around the coast of the island in about a score of visitas averaging 6 to 10 families in each. Batan, the largest barrio, has, according to the *teniente,* eighty men, which may be taken to mean nearly that many families. Taking into consideration the isolated dwellers in the hills, some of whom are Negritos, a fair estimate of the total native population of the island would be 2,000. Besides these there were at the time of our visit some 30 Japanese miners at Calanaga Bay and a detail of 15 American soldiers at Liguan under the charge of Lieut. H. L. Wigmore.

The natives were found to be peace-loving people, kindly, and thrifty compared with other tribes living close to the large cities. Their chief occupation is that of fishing, for which they make use of immense corrals constructed out of bamboo and rattan. These people treated our party at all times with respect and did all they could to help us. Among the most pleasant experiences had during the season were the stops made at the various barrios where we were invited to *bailes* and other social functions. Many pleasant evenings were spent teaching these people the idiosyncrasies of the English language. In the majority of cases Spanish was the medium of intercourse, but English is making rapid advance in the favor of the people.

HYDROGRAPHY.

Very little can be said in favor of the water supply of the Island of Batan. At the time of our work there was no running water to speak of in any stream of the Island. The largest watercourse is that of the Caracaran River which drains the greater part of the western half of the island and debouches into the bay of the same name on the south side and midway between the east and west extremes of the island. The Mosaga, which reaches the Rapurapu Straits about halfway between San Ramon and Batan, was found to have a fair quantity of water but almost no current.

The water for all drinking, toilet, and cooking purposes was obtained from a spring on Cacraray Island across Coal Harbor from Liguan (see large map in pocket).

Lieutenant Wigmore estimated by means of reservoir and weir that 100,000 gallons daily were available in all seasons.

At Tinicauan, the first barrio east of Liguan, there is a small stream which Lieutenant Wigmore also estimates may yield 20,000 gallons daily with properly constructed reservoirs. For drilling purposes all the water had to be pumped, or hauled up by carabaos, from sea level. This constituted one of the chief items of expense in the work carried on by Lieutenant Wigmore.

The small size of the island and comparatively low elevation mean lack of large feeding areas for streams; this, coupled with the broken and porous nature of the limestone formations, militates against the collection into any one large watercourse of a great quantity of water. This will be one of the drawbacks to exploratory work with diamond drills in this area.

TOPOGRAPHY AND PHYSIOGRAPHY.

Topographically Batan Island is quite rugged and broken, and for its size appears to be very mountainous, though none of the elevations rise to more than 1,400 feet. By Coast and Geodetic triangulation Mount

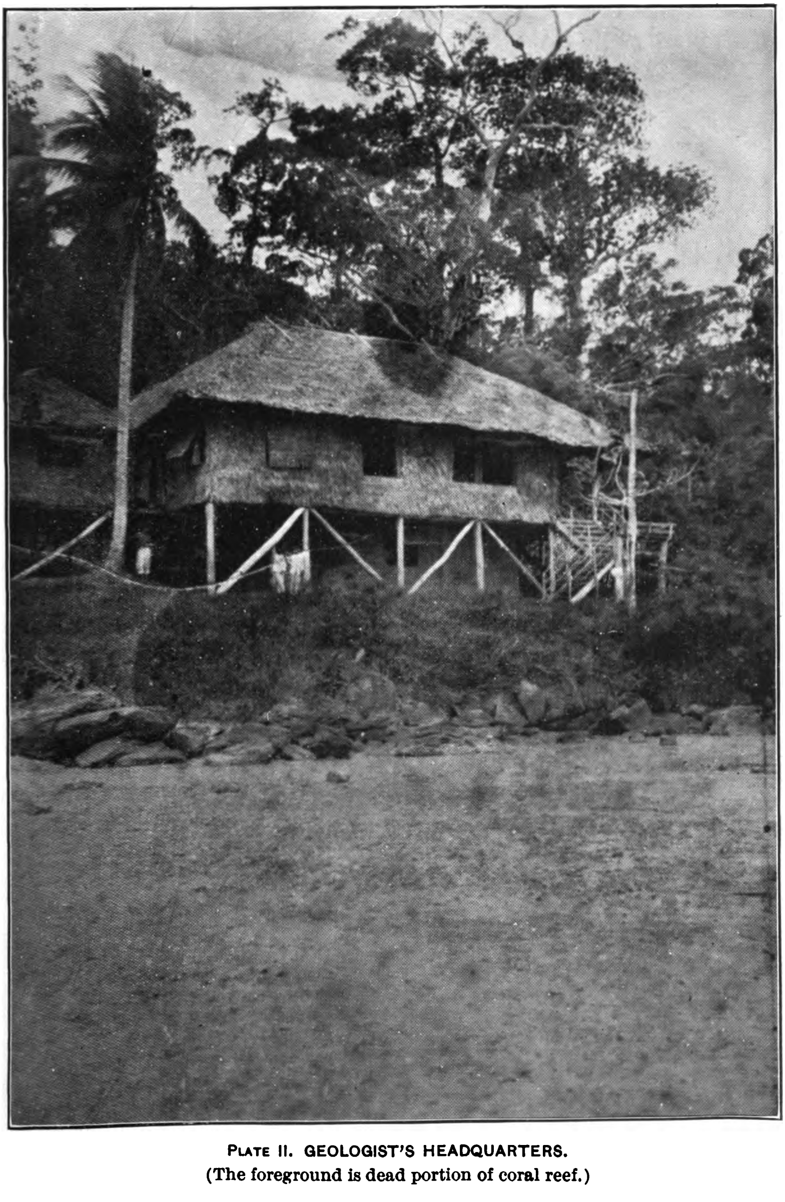

PLATE II. GEOLOGIST'S HEADQUARTERS.
(The foreground is dead portion of coral reef.)

formation when all other outcrops were concealed by soil and und

Viscaya (1,330 feet) was found to be the highest point, but even this estimate is too high, for the observations were taken from a boat and the tops of trees used instead of the actual surface, which is obscured by the dense vegetation.

By inspection of the map it is seen that the high land is adjacent to the coast and that the interior is low. Along the United States military reservation boundary from Caracaran Bay to Gaba Bay it is everywhere under 200 feet; also it can be seen that the greatest elevations are bordering the southern shore. The reason for this is that the hills are here largely limestone, while to the north they are composed generally of soft sandstone and shales. However, Mount Bilbao is an exception. The eastern end of the island is quite generally lower then the western half. One of the most striking features topographically on Batan Island is the long bare ridge extending from Calanaga Bay eastward to East Point (Pl. IV). This will be referred to again and explained.

The topography of the remainder of the Mayon area will not be discussed now, as it will be reserved for a later report.

Plate III shows a sketch profile of the island from the south side.

As the whole island is practically a monocline, with alternating hard and soft strata, the effect on the streams is to produce monoclinal shifting to the north.

The effect produced by the different character of the beds is very marked as one goes up the main stream of the island, the Caracaran, for during the first half mile or so the bed is in limestone and gorges are frequent; on the other hand, when the friable shale and sandstones are reached the stream flows in a wide, shallow valley bottom and meanders are the rule. Ordinarily a stream meanders only in its lower course, but here the upper course has reached a graded condition first.

Another feature which rightly comes under this heading is the presence of numerous sink holes in the limestone, particularly in the lower beds. These are from 50 to 100 feet in diameter, usually circular, and 25 to 30 feet deep. It is interesting to calculate the quantity of $CaCO_3$ removed from just one sink of these dimensions. It is calculated that 9,228,240 pounds of lime and 16,479,000 of $CaCO_3$ have been removed to leave a sink hole 75 feet in diameter and 25 feet deep. A great part of this $CaCO_3$ in solution is deposited long before sea level is reached, but still a considerable quantity doubtless reaches the sea and must add greatly to the available supply of lime to be used by the little reef builders. In the beginning, when the old volcanic stump first rose from the sea, the process of reef building was undoubtedly a much slower process than at the present time, but now after great masses of coral limestone have been formed the tearing down, solution, and reprecipitation in coral form constitute a cycle of changes much more rapid and continuous.

Deposits of calcareous tufa or travertine were found invariably incrusting shale formations and proved invaluable as guides to the underlying formation when all other outcrops were concealed by soil and undergrowth. These deposits were never found on the limestone itself. This deposit attains thicknesses amounting to 2 and 3 feet, completely concealing the underlying rock. It has a very cellular structure and is usually of a yellow, ochery appearance. The structure is that of concentric layers separated by minute spaces, as indicated in the diagram.

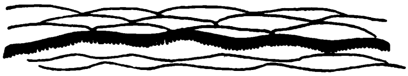

FIG. 1.—Cross section of travertine deposit.

No caves were found on Batan Island, but on Cacraray Island there are quite a number, and they have played, according to tradition, a prominent part in the history of these Islands. Indeed, it is from one of these caves in Post-Pliocene coral limestone that the crania were taken which the eminent traveler and collector, Jagor, sent to Berlin and which Virchow[1] described.

STRUCTURE.

Some discussion of the folding occurring in the island has already been entered into, but attention is called to the several cross sections taken along different lines across small areas of the island and the larger generalized section across the whole island. These will outweigh any amount of verbal description.

There yet remain to be considered such topics as faulting, dikes, and kindred phenomena so vital to mining operations. As one walks along the shore at low tide where good sections may be had of the strata—for example, near the western side of Moncao Bay, Batan Island, and near Cawauan on Cacraray Island—minute faulting from a few inches to 1 or 2 feet may be seen, but faulting to a greater degree than this the writer has not yet seen either on Cacraray or Batan. Examination of the drill records and the topography in many localities, however, strongly suggest faulting of even a greater degree. One case is that shown by the records of drill holes No. 4 and No. 4 A, located on the Urgera claim near Liguan, where a discordance is fairly evident; and it is believed by Lieutenant Wigmore that there is a throw here equal almost to the thickness of the coal measures. This is, he says, borne out by the fact that the upper limestone of No. 4 is much like that in the bottom of No. 4 A, and by the abrupt change of surface indications between the two holes. This is quite true, but simply the similar appearance of the limestones can not be taken as conclusive proof of indentity. In the absence of some one striking and wholly distinct stratum which can be used as an indicator, the question can not be definitely settled.

Another example might well be shown of what may be a fault, though the evidence is as yet not complete.

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[1] *Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin*, Berlin, 1897. January-June, 279-289.

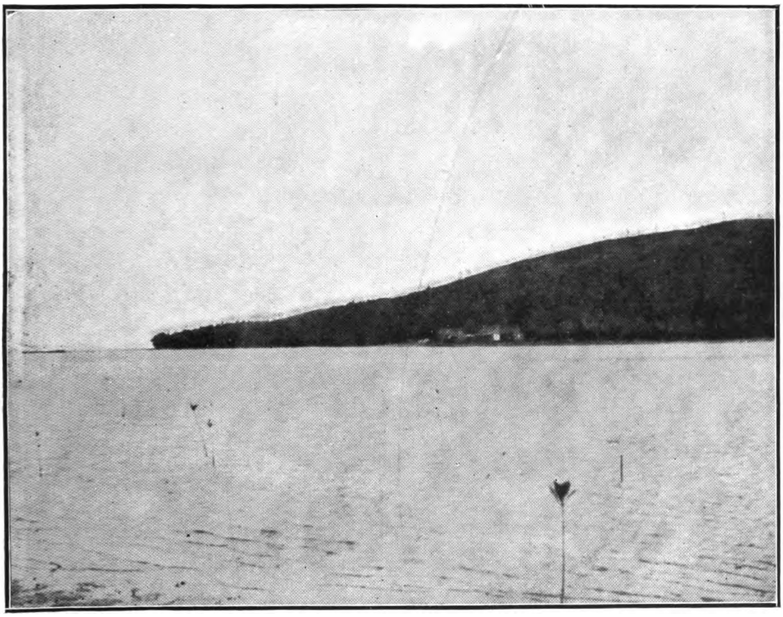

PLATE IV. CALANAGA HARBOR AND RIDGE RUNNING EAST.

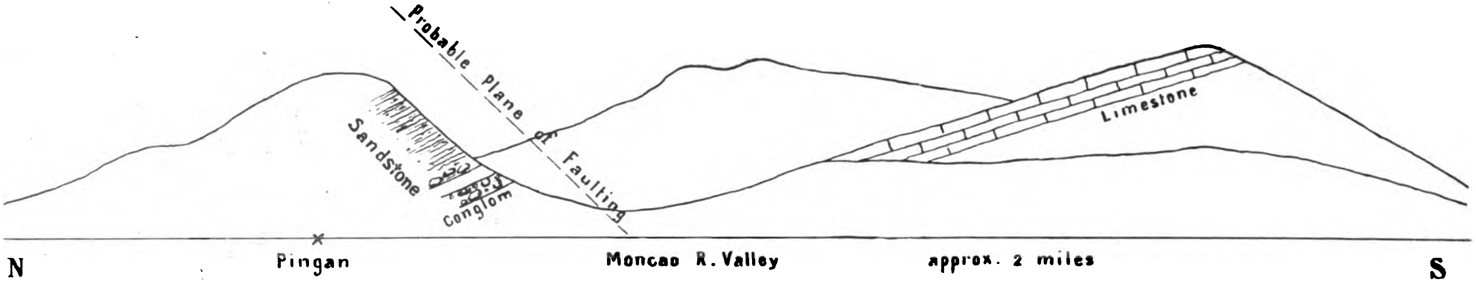

FIG. 2.—Diagrammatic section north and southwest end of Batan Island.

However, simple removal by the ordinary processes of erosion might account for the conditions indicated in the diagram.

Preceding the American occupation some mining work was done on the old Urgera claim, but the work was abandoned for the reason that the coal seams ended in a fault. The direction of this fault is east 10° south, with a hade of 10° south. The tunnel was never extended farther, so that we do not know how extensively broken up this seam is.

Further work on specimens in our possession used in connection with the drill records will probably reveal no inconsiderable faulting in the vicinity of Liguan. It is not believed that any appreciable faulting has occurred in the eastern half of the island.

At this point it might be well to discuss briefly the effect of the proximity of volcanoes to a coal field. There seems to be a prevailing idea in the minds of many that a volcano in the neighborhood of any series of sedimentary rocks would cause the strata to be much disturbed and broken up. Let it be once for all understood that a volcano is a point of relief, and that its effects, sometimes so appallingly destructive to human life, are almost negligible in comparison with the effects produced in the great regional movements of the earth. If the strata on Batan Island prove to be very much disturbed the cause should be attributed rather to the great regional movements of the outer zone of the earth, and not to the presence of volcanoes. Geologically speaking, vulcanism is constructive and not destructive.

Some mention should also be made here with reference to the hydrography of the coast and the intervening straits. Chart No. 4221, Coast and Geodetic Survey, which we find impracticable to reproduce at this time, shows clearly the very recent connection which must have existed between the "mainland" and the small islands of San Miguel, Cacraray, Batan, and Rapurapu at no very distant period. We take it that the numerous straits and passages represent faults, though the evidence is not yet sufficient to make this conclusive.

GENERAL GEOLOGY.

In general, the region comprised within the Mayon area is volcanic and of a recent age. Batan, however, is composed largely of sediments, somewhat complexly folded, but with a general northward dip at an angle of about 20°, resting, in a portion of the island at least, upon a basement of igneous rock. Fossils from the various formations on Batan Island point to the age as extending from the Eocene through the Pliocene and even the Pleistocene. Coral fragments not greatly unlike living species were found in drill cores from 300 feet below sea level, and in the limestone capping to the hills at 1,000 feet in elevation.

On Batan Island there appear to be three distinct sets of limestone and three sets of coal measures, and another series of alternating shales and sandstones running along the north side of the island. These are the barren measures. There is a long, bare ridge on the east end of the island

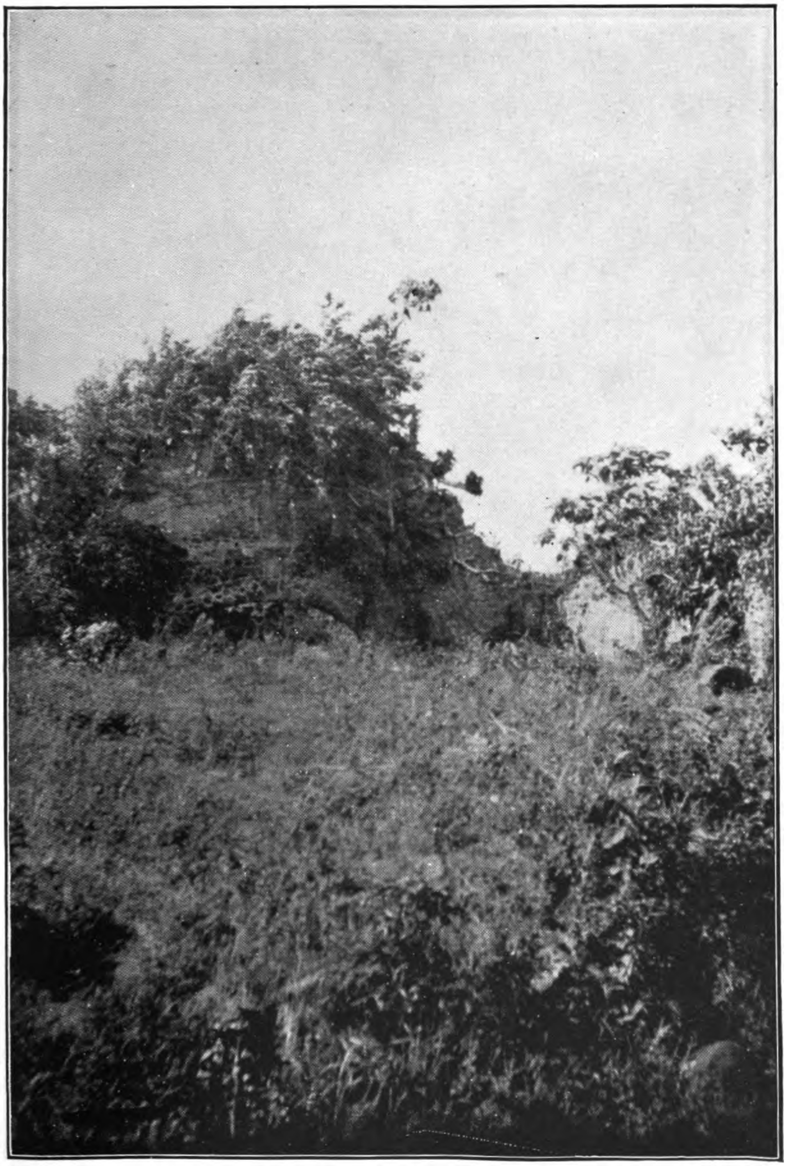

PLATE V. INTERIOR OF RUINED CHURCH AT DARAGA

which is a solid mass of dolerite overlain by the remnants of an iron formation. This dolerite barely emerges above sea level in two other places on the island, near the barrio of Caracaran, where it protrudes in a tongue-like mass about 50 feet high and 100 feet across at its base.

Coralline limestone caps the hills, while the valleys and coves are in the softer formations.

It has been said that the strike of the beds is in general east and west, but locally the strike and dip change owing to a secondary cross folding which has made local anticlines in the strata. For instance, the high point in the vicinity of Liguan and the Government post is the summit of a roughly domed mass of strata produced by folding along two directions, north and south and east and west. The ridges and spurs, generally speaking, indicate limestone, while the coves and inlets invariably are formed in the softer shales and sandstones where local synclines or monoclines occur.

Cacraray Island, to the west of Batan, is not greatly different from Batan Island geologically, though no coal has been found on it up to this time. It is practically covered with rugged, cavernous limestone through the southern half of the island, while in the northern half of its west coast, bordering Sula Pass, the formation is igneous and apparently of the same rock that is found on Batan. This passes into a gneiss as we go northward. In general, the strata of limestone and sandstone dip to the northward at an average angle of 20°.

Rapurapu Island is quite different from the others, being almost entirely made up of crystalline schists whose strike corresponds to the east-west orographic trend of the island. They have a dip of 20° south 10° west. At its western extremity, Point Baybayon, the same dolerite was again encountered with large bowlders of iron ore above it; and passing eastward along the coast the dolerite was found to be replaced by a lighter rock which we have at the present time classified as diorite. (See Pl. XIX *a*.) It is this diorite that has been made schistose in the orogenic movements in which the island was given birth; and also this schistose diorite is the home of auriferous quartz.

Coming now to the adjacent region on the Albay coast, we find in the vicinity of Sugot Bay an area of stratified deposits including coal measures which are a continuation, it is believed, of the deposits on Batan Island. From this point northward to the Camarines the geology adjacent to the coast is that of recent vulcanism, as witnessed by the following extinct and active cones; Mount Heilprin, 3,606 feet elevation, between Bacon and Legaspi; Mayon, 7,943 feet, near Daraga; Mosaraga, west of Tabaco, 4,387 feet, and Mount Molinao, 5,436 feet, just back from the coast near Tibi. All of the volcanoes are, with the exception of Mayon, which is dormant, apparently extinct. From a rapid examination of parts of this highly interesting area the sequence in the lava flows appears to have trachyte to basalt or from acid to basic. The great eruption of 1814 was marked by flows of basalt and showers of lapilli and ashes.

Nineteen hundred was the year of the last pronounced demonstration by Mayon, and at that time the main highway between Legaspi and Tabaco was partly obliterated by a flow which reached the sea near the pueblo of Libog.

We shall leave this interesting chapter with these incomplete statements for the present, for the reasons that this preliminary report is to deal primarily with the economic phases of the field work, and further work in this region of a more purely scientific nature is contemplated for the near future.

On Catanduanes Island, situated about 18 miles to the north of Batan, coal deposits have been reported from the vicinity of Ilacaang, while the central portion of the island is said to be, by Lieutenant Kirkman of the Eighth Cavalry, United States Army, made up of metamorphic rocks, including schists in which auriferous quartz veins were seen.

Coal is known to exist in Sorsogon Province, near Guijalo, and also near Laguna de Bato, in the southern portion of Ambos Camarines, and still further north the Island of Polillo is being vigorously prospected now. From what the writer has himself seen of some of these localities, and from the reports by Lieutenant Wigmore, and Lieutenant Wray of the Philippine Scouts, they are all isolated portions of one large coal field disrupted and separated through widespread regional movements of the whole eastern terrane.

Briefly the geological section can be tabulated provisionally as follows:

Provisional tabular statement of stratigraphy.

Age.	Formation name.	Contact relation.	Lithologic character.
Pleistocene and recent.	Mayon series	Unconformity	Trachytic and basaltic flows and tuff deposits.
Post-Pliocene	Galicia sandstone and shales.		Thin sandstone and shale beds alternating; very soft.
Pliocene or Post-Pliocene.	Bilbao limestone		Brecciated beds with shales intercalated.
Miocene	Bilbao coal measures		Lignite seams interbedded with shales, etc.
		Unconformity ?	
Miocene	Caracaran limestone		Foraminiferal limestone; Operculina complanata beds.
Eocene	Liguan coal measures (second stage).		Interbedded coal seams, shales. and grits.
Do	Liguan limestone (second stage).		Coralline contains numerous sinks.
Do	Liguan coal measures (first stage).		Interbedded coal seams, shales, and grits.
Do	Liguan limestone (first stage).		Coralline with intercalated shale beds.
Do?	Rapurapu, iron formation.		Iron formation; no distinct stratification.
		Unconformity.	
Pre-Tertiary?	Basement complex		Peroxinite and peridotite intruded by diorite serpentine.

The large, 2,000-feet-to-the-inch map of the island has been prepared to show the general geology of the whole island, the topography, and location of towns, trails, mining sites, and claims. The prominent hill-tops were located by triangulation by the Coast and Geodetic Survey. The topography is, for the most part, sketch work, but checked by data obtained by traversing, so that it has been made quite accurate as to the main features. The extraordinary jungle growth made this portion of the work well nigh impossible on a more detailed basis. On the same map there are shown, by means of dotted lines, the areas, which have been mapped more in detail, of the present and past mining sites.

DETAILED GEOLOGY OF BATAN ISLAND.

Confining our attention now to the Island of Batan, we shall take up its geology in somewhat greater detail and with special reference to the coal deposits.

IGNEOUS BASE.

At the base of all the formations exposed on Batan Island there is a dark-green, fine-grained rock, at times showing marked porphyritic facies, which constitutes the long ridge from Calanaga Bay to East Point, and outcrops in a large tongue-like mass at the entrance to Caracaran Bay, near the barrio of the same name, and again is seen as an outcrop on the shore at the visita of Liguan. This rock was also found as a float in two other places on the island, and they are of considerable consequence in their bearing on the geology of the economic deposits of the district. One of these is at Bilbao, where it was seen in the trail near the miners' camarine, and the other in the interior of the island in a small tributary of Caracaran River near its head waters.

It would seem in the light of these findings that the sediments in which the coal seams are included were more of the nature of a veneer of ocean-made débris laid down on the worn-down stump of a volcanic pile and raised to their present position by subsequent differential thrust from below. It is the writer's conception that phenomena somewhat analagous in the main to those recorded by Mr. R. T. Hill [1] in his recent discussions of the evolution of the Windward Archipelago also obtain here, not only in Batan but in many islands of the Philippine group. If this be true there seems to be no great encouragement to deep mining, at least on Batan Island.

THE IGNEOUS ROCK.

Megascopic.—In the field this rock is seen to grade from a fine-grained dark-green, almost black, basalt (f. n., field and quantitative classification of igneous rocks[2]) to a porphyritic rock with large pyroxene crystals over an inch in length, and from this to a true serpentine. Specimens are at hand which show the merest remnants of the original rock included in a network of greenish serpentine and white magnesite. The serpentine and magnesite are only found on weathered faces such as along the seaward cliffs of the long bare ridge running from Calanaga Bay to East Point.

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[1] R. T. Hill: "Pelé and the Evolution of the Windward Archipelago." *Bull. Geol. Soc. of Am.*, vol. 16, pp. 243–288, 1905.

[2] Cross, Iddings, Pirsson, and Washington: "*Quantitative Classification of Igneon Rocks.*" Chicago, 1904.

In the vicinity of Liguan and Caracaran only the fine-grained aphanitic facies was seen.

As one skirts along this great ridge of serpentinized rock he is struck with its likeness to similar rocks along the California coast.

Microscopic.—When studied microscopically the rock is seen to be not a basalt in the commonly accepted meaning of the word, as the feldspars are characteristically lacking. In the less-altered sections the chief minerals were found to be olivine, a pyroxene or amphibole (not readily distinguished from the alterations), and magnetite. The whole section is seen to be a network of serpentine even though the hand specimen does not show it. (See Pl. XIX *b.*)

This rock was called a basalt by Lieutenant Markham, but that identification was made simply from a hand specimen hastily examined in the field. The rock is more of a peridotite than anything else, though it grades into a pyroxenite. The writer has examined microscopically identical rocks from the Coast Range of California.

Lieutenant Markham also refers to sedimentary beds intercallated between successive flows of this igneous rock. The writer saw no such phenomenon as this on Batan Island. What probably led Lieutenant Markham to make this statement was a pseudostratification simulated by the secondary structure jointings, shearing planes, etc., which are quite prominent along the north shore of the island. This jointing occurs in two sets, one with a dip of 65° and striking north 45° west, and the second, less marked, dipping 45° and striking north 75° east, differing not essentially from the tectonic line as found on Rapurapu Island.

Analysis.

	Per cent.
Moisture at 110°	0.73
Loss on ignition	8.27
SiO_2	39.16
Al_2O_3	3.76
Fe_2O_3	4.32
FeO	3.55
CaO	2.08
MgO	38.15
Na_2O	.70
Total	100.72

Specific gravity, 2.88.

IRON FORMATION.

Resting on top of the igneous base is the remnant of a formation which was formerly in all likelihood very extensive and possibly quite thick, but now is represented by a few huge bowlders of hematite and limonite on the slopes and even summits of the ridge from Calanaga Bay to East Point. Its former extension over other parts of the island is also attested by the presence, on the seashore near Liguan, just above the igneous rock, of pebbles and small bowlders of iron ore. Also by the presence of great quantities of quartz pebbles in the conglomerate at the base of the coal measures.

It is known that quartz in veins is of frequent occurrence in the iron deposits of the Lake Superior region. A similar source, it is believed, must be accountable for the great quantity of quartz in the basal beds. If such an iron formation carrying quartz in the form of veins were subjected to the processes of erosion, the quartz, being the most refractory constituent, would, of course, be the last to disintegrate and be worn away by streams and the wash of the waves. As the igneous rock referred to contains no free quartz whatever, we are driven to this conclusion.

This old iron formation was found again occurring on the western end of Rapurapu Island, resting as before upon the same igneous rock, but it is more extensive there than on Batan Island. As before, no regular bedding could anywhere be made out, but huge bowlders of it were everywhere to be seen.

At Babayon Point, on Rapurapu, an exposure of both igneous rock and iron formation was visited which showed the relations sketched below in the diagram:

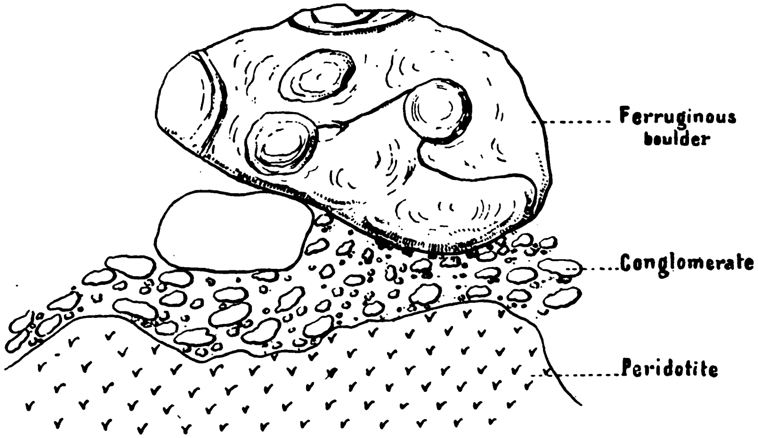

FIG. 3.—Conglomerate on Babayon Point.

At first sight the conglomerate was taken to be the basal conglomerate between the igneous rock and the iron formation, but after some search pebbles of iron ore were found sparsely scattered throughout the conglomerate with igneous pebbles. This conglomerate represents merely a conglomerate forming at the present time.

Analysis of the ore.

Constituent elements.	Batan ore.	A standard Lake Superior limonite from the Mesabi Range.
	Per cent.	*Per cent.*
Moisture at 110°	3.46	8.25
Loss on ignition	16.68	1.3028
SiO_2	11.32	3.303
Al_2O_3	15.13	.6973
Fe_2O_3	[1]50.33	[2]
FeO	[1].08	
MnO	1.65	.3211
CaO	.47	.2891
MgO	.14	.1358
P_2O_5	[3].08	.0348
S	.18	.0037
TiO_2	.10	
Total	99.62	

[1] Fe = 35.23. [2] Fe = 58.8118. [3] P = .035.

Specific gravity, 3.42.

As the lowest economic limit for the iron content is about 50 per cent as a rule and is generally 53 per cent (though at Iron Mountain, Michigan, ore running as low as 47 per cent in iron is said to be capable of Bessemer treatment), it will be seen that this Batan ore is far too low for any such treatment and we believe of too low a grade for any profitable treatment at all. The phosphorous content is well within the 0.045 limit, usually taken as the standard limit in iron ores. The percentage of sulphur is so small as to be practically negligible.

EXTENT OF IRON FORMATION.

As yet the writer has seen iron ore on portions of these two islands only, and occurring, as before noted, in patches, remnants of a more extensive formation. It may be found—indeed, it is quite probable—that this remnant was once coextensive with the iron formation in the Camarines, and even with that farther north in Bulacan. An examination of the associated rocks from the Bulacan iron-ore deposits leads us to be strongly of this opinion. At the earliest opportunity an examination of the geology of these deposits will be made for the purposes of correlation.

ORIGIN OF IRON FORMATION.

The great ore deposits of the world are, almost without an exception, sedimentary deposits and hence of secondary origin; and, further, they are associated in nearer or remoter degree with igneous rocks. The igneous rocks were the original home of the iron; meteoric water has been the agent in leaching out, transporting, and depositing the ore.

Within the last few years rapid and radical changes have taken place in our knowledge of the principles involved in the origin of ore deposits. At the risk of reproducing material perfectly well known to some, and also of appearing too academic in a report of this nature, we shall briefly outline the general principles of the origin of iron ores for the benefit of those to whom the literature of Van Hise[1] and others is not available.

In the igneous rocks are many minerals among whose constituents is iron, but it is as iron in combination, not as metallic iron (though exceptional cases of original metallic iron in igneous rocks are known, as also the presence of it in meteorites). A few of these minerals are magnetite, Fe_3O_4, and a host of complex silicates, of which augite, actinolite, and olivine are the chief.

Through weathering, these rocks are broken up and the minerals decomposed. The iron, with aluminum and other elements, becomes combined with oxygen and water, and various carbonates and hydrates are formed, but iron usually is taken underground in the form of $FeCO_3$. When the water bearing iron carbonate in solution comes to the surface the CO_2 is liberated and the oxide is hydrated and limonite formed.

In the early part of the process the water is descending; in the latter part it is ascending, as a general thing.

But besides the action of meteoric water we must consider the little-known work of an insignificant little group of organisms which probably have had greatly to do with the formation of deposits of iron ore. It is well known that there is a group of bacteria, which swarm in the bulbs of certain leguminose plants, capable of extracting, in some way, not yet perfectly understood, nitrogen from the air. This has recently been employed in a practical way in agriculture for inoculating, as is were, soil which has become depleted of its nitrogenous matter. So there is a group of bacteria, too, which is capable of "fixing" iron. Just how much is due to the action of low forms of plant life decaying in swampy places in contact with precipitates of iron oxide would be interesting to know.

We shall refer again to the action of these lowly organisms when we reach the subject of the deposition of coal deposits.

Now, in the case of the Batan and Rapurapu deposits of iron ore, we have the igneous rock immediately below the iron formation. Petrographic examination of this rock shows it to contain minerals rich in iron, magnetite being abundant in the section. Ascending waters leached this rock of its iron, carried it up into the formation, whatever it may have been before, and replaced it, molecule for molecule, with iron-oxide molecules. From an analysis this would seem to have been the case, as not inconsiderable percentages of silica (SiO_2), alumina (Al_2O_3), manganese oxide (MnO), traces of lime (CaO), and magnesia (MgO) appear to represent the existence of an antecedent formation.

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[1] C. R. Van Hise: "A Treatise on Metamorphism." *Monograph XLVII, U. S. Geol. Survey, 1904.*

VALUE OF THESE DEPOSITS.

It is almost certain that this iron ore will have no economic value, both from its low iron content and its scattered distribution, though there must be several hundred, possibly a thousand, tons of it in sight. The Bulacan deposits, nearer to Manila, of high grade and extensive, will, of course, settle the question.

These deposits are, however, as has been said, very important to one interested in the broad problems of stratigraphic correlation.

THE COAL MEASURES.

We come now to a consideration of the most important series of all the formations in the Mayon area—the coal measures. The use of the words "coal measures" is restricted to the series of shales, grits, and sandstone in which we find the coal seams and does not include the great beds of limestones which separate the several coal horizons.

There are three distinct coal horizons on Batan Island, the highest of which has been the only one to be exploited commercially, but recent exploratory work has shown the two lower horizons to be much more valuable. Beginning with the lowest horizon we find a "grit" of variable thickness, the exact amount of which could not be determined, as the drills did not penetrate it entirely, nor could much be told from the exposures, owing to the heavy mantle-like talus which makes the prospector's and geologist's work exceedingly difficult. Above this "grit," which, by the way, becomes less coarse the farther removed geologically from the igneous rock and iron formation, is a rather complex series of shales, sandstone beds, and coal seams. By referring to any of the drill records (Nos. 11, 11 A, and 13), a fair idea of these coal measures is to be had. Drill hole No. 13, for instance, shows twelve seams of coal, the thinnest being 6 inches thick, while the thickest is 3 feet 9 inches. It is estimated that the total thickness of this lower series is over 300 feet, and may be even considerably more. No reliable means of telling are at hand, as the drill did not reach the lowest part of the measures in any place.

An examination of the drill record of No. 13, and others as well, will make it clear that there is no constancy in the character of the beds above and below the coal seams. In some cases there is a "grit" just above the coal with shale below it, then again these conditions are reversed and the shale is above and "grit" below the coal seams, with no other indications of overturn. This "grit" is probably equivalent to Verbeek's quartz sandstone stage or stage II of the Eocene.[1]

By referring to the geologic map the surface extent of this formation can be seen. Some portions of the boundary lines will be open to revision when some of the jungle is cleared away and more outcrops are obtained.

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[1] *Die Eocänformation von Borneo und ihre Versteinerungen*, 1875, p. 4.

This set of coal measures is found beginning at sea level with a lateral extent from the limestone escarpment just east of Liguan westward along the coast to a point halfway between Liguan and the Government post storehouse, thence running as a broad belt up the slope of the hill to the northeast, swinging around more and more to the east when an elevation of 300 feet is reached.

As one walks along the beach eastward he comes soon to limestone cliffs which continue almost to Tinicauan, the next visita eastward, when coal measures come in again.

From about where drill hole No. 13 is located limestone is the surface rock all the distance to the storehouse, then comes a break in the limestone where coal measures succeed for 600 or 700 feet. From this point northwest the limestone continues almost without a break to Moncao Bay. These measures and limestone beds follow the same general course northeast only to swing eastward higher up on the slopes of the mountain. How thick this second limestone is would, indeed, be hard to conjecture, though we might form some idea from its horizontal outcrop and its angle of dip. By the well-known rule that the thickness equals horizontal outcrop times the sin of the angle of dip, we would get a rough estimate, but not an exact one, as erosion has planed off some of its thickness and land slipping has brought overlying coal measures down farther than they really belong. This computation would give 170 feet for the probable average thickness, which is, if anything, too low.

When we come to the uppermost beds of limestone, the bottom of which is somewhere in the neighborhood of the 500-foot elevation, a greatly increased thickness is found, for from this elevation to 1,000 feet, the summit of the ridge, is limestone almost continuous save for one or two minor partings of shale which are to be found in any great mass of limestone strata.

It has been found that this general sequence of beds prevails in the entire island from west to east, but these formations have not been mapped with any such degree of minuteness on the eastern half as on the ground included in the Government reservation. This is work laid out for the future when it shall have been decided to develop the coal deposits of the district, and until such time it were useless labor, as every foot of the ground traversed necessitates the use of the bolo.

In the eastern portion of the island, off the reservation, coal deposits were found on the south side in the vicinity of the barrio of Dapdap and of the pueblo of Batan, dipping fairly constantly to the north, or a trifle east of north at angles of 10° to 20°, and also on the north side of the island at Bilbao and Calanaga, also dipping to the north at 20°. Considering the distance apart and the angle of dip, the beds on the north and south sides could not be made to correlate. The natural tangent of 10° in a distance of even 1 mile would cause the beds of the southern half to be projected far below the Calanaga seams. However, folding might bring them up again, but a fairly close inspection of the intervening country by Lieutenants Markham and Wigmore, Mr. Oscar Halvorsen, former superintendent of explorations, and the writer revealed north and northeast dips only.

With what beds in the Liguan series are we to correlate these eastern outcrops? Those exposed on the south side of the island undoubtedly are continuations of the lower series near Liguan, as the writer found isolated outcrops at intervals of one-fourth to one-half mile all along the slopes of the southern range of hills and always with a general northward dip and east-west strike. But when we come to correlate the Calanaga series there is more difficulty. From the very incomplete and preliminary work which the writer up to this time has been able to do on the stratigraphic problems of this district, it is his opinion that the Calanaga beds are very much higher and hence younger geologically than the Liguan series. Possibly they are to be found continuous with a bed outcropping near the head of Moncao River, at 300 feet above sea level, on the northeast slope of the Liguan ridge. The appearance of the shales beneath and the limestone above with the included fossils seem to bear out this view. No specific studies of the fauna of these beds have yet been made—merely general examinations so far—but even this has shown that they both have a very modern aspect. This comparison of faunas is a very slow and difficult work, but oftentimes the only means of correlation.

When possible to employ purely stratigraphic principles the work of correlation is apt to be surer, but in the absence of continuity and uniformity in the beds, as here, we must depend largely upon paleontologic features.

Further search may disclose the fact that these Moncao deposits simply continue around the contour of the hill and connect with the upper set of coal seams on the Liguan side, leaving the Calanaga seams in a higher horizon not found or at least not discovered on the north side of the Liguan ridge.

It is thus seen that the problem of the contiguity of the seams and their correlation is by no means settled as yet. For the accomplishment of this much-desired end more detailed prospecting in the jungle and more extensive, systematic, and deeper drilling is absolutely imperative before the whole truth be known.

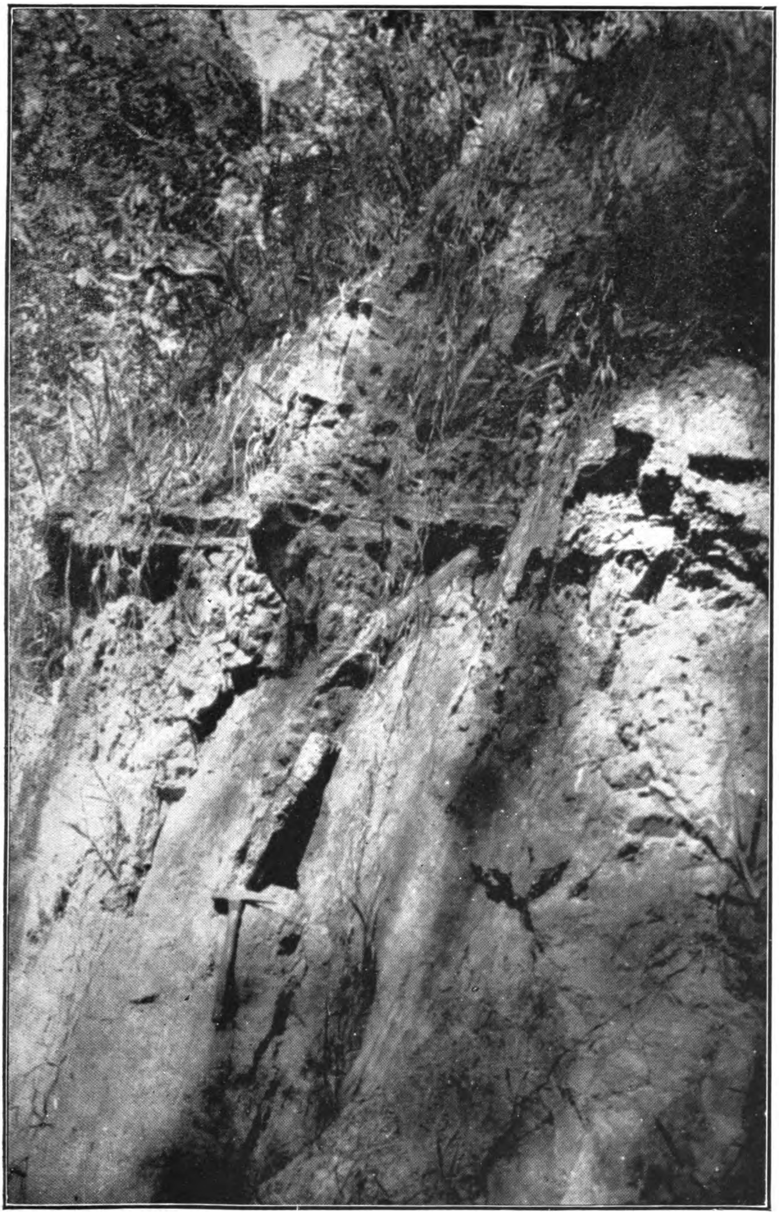

PLATE VI. FOSSIL TREE IN COAL SEAM.

ORIGIN OF THE COAL MEASURES.

It might be thought the origin of coal a question settled for all time, but recently work has been done by a German scientist, Donath[1], whose literature, however, we have not been able to obtain up to this time, which purports to have outlined a new theory. As near as we can make out from what we have been told by one of our colleagues in the Bureau of Government Laboratories, who has visited this scientist in his laboratory in Germany, the new theory stipulates an animal origin—or, more precisely, animal agency—in the process of coal making. If he means by that some low form of lifelike bacteria acting upon decaying cellulose, then we see some substantial grounds for the use of the word "animal." Such an explanation would fall in very nicely with what we know does take place in the formation of iron by these organisms. But this is no new idea by any means.

It is highly probable that the coal formed within the Tropics may have been deposited largely through the agency of the teeming organisms which flourish there, but all coal was doubtless formed at times when those localities in which it is now found were tropical in nature.

Putting away opinions and theories, the facts as we find them to-day in this part of the Tropics appear to be these:

(1) The coal was formed from accumulated vegetation.

As evidence, the numerous leaf impressions preserved in and associated with the coal beds; tree trunks, whose roots are in one bed and whose tops are in the seam above (see Pl. VI); the woody structure of the younger and less consolidated beds at the eastern end of Batan Island.

(2) The coal was formed in tidal swamps.

As evidence, the character of the vegetation whose remains now appear in the associated beds, they resembling very closely the vegetation now growing in the tidal swamps of the present.

(3) Remains of marine shells, mollusca, and echinodermata are found in the shale above and below the coal.

(4) No great amount of animal remains, sufficient to have formed the coal independent of other agencies, are anywhere found. Of course we could not detect the former presence of bacteria and similar forms of life.

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[1] E. Donath: *Betrachtungen über das Backen und über die Bildung der Steinkohle, Zeit. für angewandte Chemie*, Heft 20, p. 490, 1902.

(Since the manuscript for this report was sent to the press the above-cited article has been obtained. In this the author asserts that anthracite and bituminous coal were of different origin from brown coal. He mentions the similarity of coke obtained from "steinkohle" Eiweisskorper. Whether in later articles he goes so far as to assert that it was formed from Plankton deposits and not at all from plants we are unable to find out. However, his whole study of coking properties and distillation products of coals, and his comparisons of these with other organic substances are highly interesting and important. Perhaps geologists have not yet settled this question by any means.—W. D. S.)

Before leaving the general discussion of the coal measures we must refer to a stratum, very thin it is true, of "clay ironstone." It was found in drill hole No. 12 at a depth of 121 feet and resting upon limestone and just below a thin bed of "grit;" it can not be over a foot in thickness. It is so characteristic that it was hoped that it might be used as an indicator in checking up the various drill-hole records, but it was never seen again and must be a lenticular body.

It is very likely to be a residuum of the old iron formation, which we saw from the analysis contained considerable alumina. The presence of the limestone below need offer no serious obstacle, as the original formation may have been a limestone, in its upper portion more or less argillaceous.

THE LIMESTONE SERIES.

From our work thus far we are able to say that there are at least three sets, possibly four, of limestone on Batan Island. It is found capping the highest points, 1,330 feet above sea level, and 345 feet below sea level. Corals not essentially different from those growing in the reefs to-day are formed at both extremes. This means that both elevation and subsidence have been a part of the island history. It means, too, that the line to be drawn between the various periods of the Tertiary can not be drawn easily, if indeed they can be drawn at all, in tropical terranes.

An attempt has been made on the large map herewith to show the extent of these three limestone horizons throughout the island, and it will be seen that they have an undulatory line of outcrop across the map. This is due to the secondary folding. The lowest series is best seen in the neighborhood of the United States military post. It is very irregular, full of sink holes, and is bluish gray and contains some coral fragments. The present reef grows right out from it. It is at least 300 feet thick, and may be considerably more. Followed to the eastward it changes locally many times. Just east of the sitio of Manila it so closely resembles a basal conglomerate that the writer was puzzled a long time to account for it, but as matrix and pebbles were of the same material it was taken to be not a basal conglomerate but the ordinary agglomerate which will form wherever cliffs are found. This may be equivalent to Verbeek's Breccia stage at the base of the Eocene.

The second or middle set is encountered as one goes up the trail above the Urgera mine. Here it cuts diagonally across the trail and swings off in a general east and west, more northeasterly, direction and passes around the hill to the north. It is the same limestone which is the capping to the hills all along the south side of the island. Now its 20° dip to the northwest brings it down to sea level at Moncao Bay and far below sea level on the north side of the island, where its dip changes to northeast. This limestone is more regularly bedded than the former but contains fewer fossils. It is in general buff colored and appears to be more compact than the lower rock.

However, it, too, has great local variation, contains sink holes, and has living reefs on its borders.

This limestone was followed eastward with considerable difficulty, and the writer believes it to be continuous with a very interesting facies which was encountered in place only in the bed of the Caracaran River about 1 mile above its mouth and as float about 500 feet up on the western slope of Mount Vizcaya. Its whole thickness could not be ascertained. This stratum contains the species *Operculina complanata* and *Cellepora formosensis* (Newt. and Holl.) in great numbers. The rock is bluish gray, coarse grained, and contains a mass of foraminiferal tests.

We should be safe in calling the thickness of this set 500 feet at a minimum, and a thickness of 1,000 feet undoubtedly is reached in portions of the island.

The third, and uppermost, of the limestone series is found above the coal measures, at Bilbao, on Mount Bilbao. It is much the same as the others, but from its geographical position and the invariable northward dip in the strata on that portion of the island it must necessarily lie above stratigraphically. It likewise dips northward into the sea, has conglomeratic facies in the region of the coast line, but much elevated, and is in juxtaposition to living reefs. A few fossils were collected from this horizon in the short time at our disposal, but have not yet been studied.

Now it may be that when the jungle has been cleared away—and even then it will be no easy work to trace outcrops—these upper beds may be found to have a fold in them which will bring them into continuity with the uppermost beds in the southern range of hills, but there is no evidence for this so far.

More or less recrystallization has gone on in the rock. Dolomitization has not gone far, as can be seen from the following analyses, and these limestones are very pure.

We have one thin section before us which has a mottled appearance due to a mixture of amorphous yellow, dark-bluish patches, and white-and-black crystalline portions. The section also shows sections of rhombs—one-half rhombs in an amorphous matrix.

Analyses of two Batan limestones.

Constituent elements.	1.	2.
	Per cent.	*Per cent.*
Moisture at 110°	0.21	0.38
Loss on ignition	43.60	42.76
SiO_2	.50	1.41
Al_2O_3	.33	.80
Fe_2O_3	.22	.29
FeO	----	.22
CaO	54.23	53.48
MgO	.27	.12
K_2O	.12	.20
Na_2O	----	----
Total	99.48	99.66

SHALES AND MARLS.

In our discussion of the coal measures we have already made some mention of the shale beds which are found alternating with the coal seams. These have been compared with those collected from Cebu and discussed by the notable geologist, Abella, and have been found to be very much the same, though a close study of the faunas of the two has been necessarily postponed. These shales belong, we believe, to the quartz sandstone stage of Verbeek.[1]

Now when we go up the Caracaran River through the center of the island we pass out of limestone, which dips here southeast in a mile or so, and come to a great series of shales dipping at first to southeast, then folding over to the north at an average angle of 20° with local variation. The river in places cuts across the strike of these beds, but in others runs parallel. The thickness of these shales is at least 10,000 feet, and in all probability twice that. An occasional bed of limestone comes in, but attains no great thickness. Taking in account the angle of dip, its thickness would not be over 25 feet.

This great series, following Verbeek, we wish to call the marl-sandstone stage.

These shales are barren for the most part, though one piece of float coal was found in the stream bed. Its origin is not known. Plant remains and carbonaceous shales are abundant.

There is an undoubted unconformity between the limestone and the overlying shale, which may be equivalent to the discordance mentioned by Mr. Becker [2] as occurring in the Miocene of the Sunda Islands.

Fig. 4 shows this; however, it is complicated by the local fold in the shale and the broken nature of the limestone.

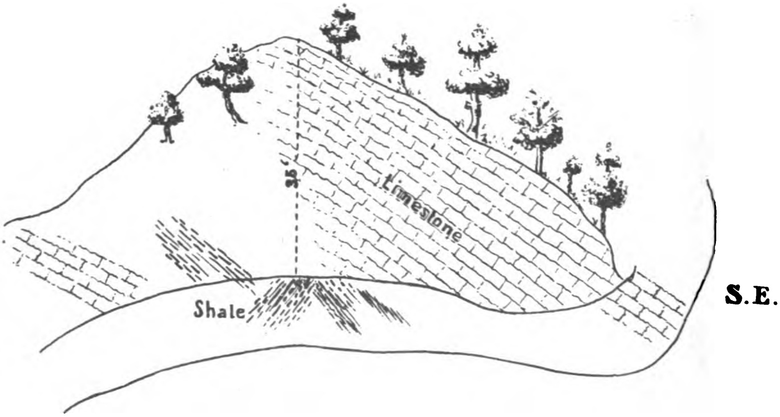

FIG. 4.—Section on Caracaran River.

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[1] *Die Eocänformation von Borneo und ihre Versteinerungen*, 1875, p. 4.

[2] G. F. Becker: *"Geology of the Philippine Islands." Extract 21 Ann. Rept. U. S. G. S.*, 1901, p. 550.

This unconformity may be seen at another place on the coast between Caracaran and the sitio of Manila. (See fig. 5.)

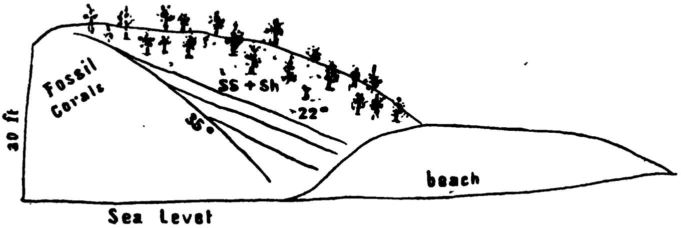

FIG. 5.—Section on coast near sitio of Manila.

We explain the limestone being above the shale in the preceding figure as due to overturn.

There is one outcrop on the southeast slope of the Liguan ridge which resembles the classic limestone from Binangonan, in Rizal Province, very much, but as yet we have detected no fossils in it. Whether or not this limestone comes in above or below the shales above described is not certain, as it was next to impossible to trace these formations satisfactorily through the jungle.

THE GALICIA SANDSTONES AND SHALES.

On the north side of the island the predominating rock is a buff-colored sandstone, fairly fine grained for the most part, and soft. It possesses good lamination, having undergone little or no alteration since its emergence from the sea. The hills on the north side of the island as seen on the large map are composed of this sandstone, and the stream gorges show some fine sections. However, this formation is not free from shale beds. Fig. 6 is a section from the falls of Galicia Creek.

At the entrance to Gaba Bay on the north shore the angle of dip is 40° north 10° west. There is a possibility here for a marked unconformity to be disclosed, though we can not trust to dips alone. The recorded dips taken from the coast at Galicia in succession up Galicia Creek to its head run as follows: 15°, 19°,-15°, 14°, 15°, 28°, 45°, 32°, 28°, 18°, 20°, with the directions of dip varying from north 45° west to due north, north 58° east, north 80° east, south 55° east to south 85° east.

On the north side of the Moncao River about a mile southeast of Pingan, in a small ravine at an elevation of 150 feet, we found a basal conglomerate at the base of this sandstone formation which may mark the same unconformity as that mentioned above.

The truth of the whole matter is that Batan Island has suffered many oscillations of level and much minor crumpling of strata.

Before leaving this subject we should refer to a statement made by Lieut. Edward Markham, whom we have already referred to:

> On the north shore of the island near Gaba, where the formations have been uncovered by heavy wave action, layers of sandstone may be seen between volcanic strata, showing clearly the intermittent character of the lava flow.

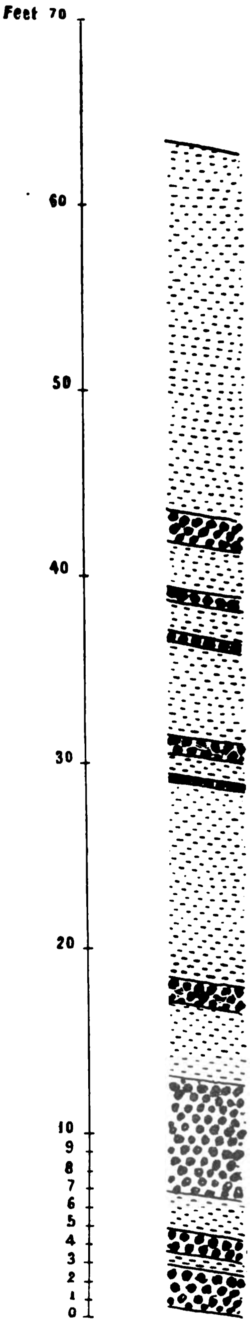

FIG. 6.—Section at Calicia Falls.

Lieutenant Markham undoubtedly took certain impure sandstone facies with fragments of mica, hornblende, etc., for volcanic rock, as the writer saw no volcanic material above the basement rock save one bomb which had evidently come from Mayon. This was found on the south shore near Caracaran.

As to the stratigraphic position of these beds, certain shaly beds near the entrance to Gaba Bay are very rich in foraminifera, some of which have been worked up and will be discussed in the last chapter of this paper. They point clearly to some stage of the Pliocene, quite likely the Upper.

ECONOMIC.

HISTORY.

The coal deposits of Batan Island rank next to those of Cebu in point of discovery and prominence. Although combustibles of this kind were discovered on the Island of Cebu as early as 1827, no mining was undertaken till the year 1853.

The first attempts at coal mining on Batan Island were begun as early as 1842, when the governor of Albay, Velarde, worked and shipped its coal from the vicinity of Calanaga Bay. In 1847 Martin Verande made claim entries, but nothing very pretentious was put on foot until 1874, when the famous "La Paz" company, which had previously been developing the Sugot property near Bacon, on the Albay coast, filed a number of claims, but before the proper proceedings had been gone through with for issuance of titles the company dissolved through lack of funds. The "La Paz" claims were named "Esperanza," "Filipinas," and "Albay," but as the concessions were never granted their locations are not shown on the accompanying map.

By referring to the admirable rapid history of the coal measures of the Philippines, compiled by Mr. Burritt,[1] former Chief of this Bureau, we find that not until 1893 were more claims taken up, and that all interest seems to have waned. But in that year claims were taken out by three different parties—the "Sodupe," of two pertenencias, by Gil Brothers, Manila, on December 20; the "Balmera," "Urgera," and "Ganalda," one pertenencia each, December 21, by Messrs. Villanueva & Co.; and the "San Francisco," of four pertenencias, by Emilio Muñoz, December 30. In 1894 there was added to the Gil Brothers' group of mines the "Bilbao," of four pertenencias, on the 20th of December; the "Lucas y Josefa," of one pertenencia, and the "Chifladura," also of one pertenencia; and to the properties of Messrs. Villanueva & Co. the "Perseverancia," of one pertenencia. In March, 1895, Gil Brothers presented petitions for the " Presentacion " and the " Olaveaga," of two p cias each. All the above concessions were granted. These repr the "first-class claims" prior to the American occupation. At the the occupation a number of claims were pending, but titles hav been granted them, and since that time only very meager work h carried on, and at this time there is no mining or development wor done anywhere on the island.

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[1] Chas. H. Burritt: "Report to the United States Military Governor in the Philippines on the Coal Measures of the Philippines." *War Department, Division of Insular Affairs*, August, 1901.

According to the best available information Gil Brothers did no their operations until 1899. A number of Spanish miners we down to begin work, but, as report has it, all got drunk and th did not proceed very far.

Work was resumed in March, 1904, under the supervision of a Ja contractor, Mr. Gato. He was succeeded for some unknown rea November of the same year by Mr. Ikeda, also a Japanese, and h tinued in charge of the work until the shutting down in the first w June of the present year.

This mine, the most pretentious undertaking in the colliery line o of Cebu, is called the " Minas de Batan." It will be referred to ag greater detail in the following pages.

In 1901 the military authorities of the Philippine division consi the matter of investigating the coal deposits of various localities i Archipelago with a view to mining the fuel for use on military tran and on naval vessels. It will be recalled that this same plan was pro several times to the Spanish Government but was never adopted, inspector sent out to investigate the feasibility of such a propositio posing it.

However, on September 7, 1901, Lieut. Edward Markham, Cor Engineers, United States Army, was detailed to make this investiga visiting the Islands of Batan, Cebu, Negros, Mindoro, Mindanao, S rara, and Surigao. On completing this preliminary investigation L tenant Markham submitted his report to the division commander March 27, 1902, recommending therein the selection of the sitio of Lig as a suitable location for Government mining. Acting upon this reco mendation Lieut. H. L. Wigmore, Corps of Engineers, United Stat Army, proceeded to Batan Island in the summer of 1903 with a detac ment of soldiers from the Engineer Corps and two diamond drills to tal up the work of further exploration.

In the fall of that year Mr. Oscar Halvorsen was sent down by the Civ Government to superintend, under the orders of Lieutenant Wigmor the more technical portion of the work. Mr. Halvorsen remained o Batan Island for some months.

In March, 1905, the writer was detailed by the Chief of the Minin Bureau to make a report on the economic geology of Batan Island an vicinity, and to lend such technical assistance to Lieutenant Wigmore a could be rendered to facilitate the work of exploration. On the 20th o

April, 1905, Lieutenant Wigmore's report was submitted to the division commander and the work of exploration suspended indefinitely awaiting the action of Congress.

Since that time only a little spasmodic prospecting has been carried on and some coal taken out by the natives for local consumption.

Such is the past history of the work and investigations on the coal deposits of Batan Island. What the future history of these coal fields will be is hard to tell. It is certain that private capital will hold aloof until two points are settled. First, it will await the action of the Government; second, it will also probably wait for a more liberal mining law, in particular upon points which relate to purchase. This does not apply solely to Batan Island, but to the whole Islands.

THE COAL SEAMS.

LIGUAN.

Brief discussion has been made, under "Geology," of the occurrence of the coal measures, and it now devolves upon us to treat the coal seams as economic deposits.

In the area wherein the lower coal measures come to the surface (see vicinity map of Liguan) there are no less than twenty-three outcrops of coal. These by no means signify that number of distinct coal seams. For the true number, thickness, and quality the records of the cluster of drill holes located near sea level should be consulted. The outcrops never give the true condition of the coal, and oftentimes the position and thickness of the seams are totally different from what is true in a considerable distance from the surface. Observations with regard to dip of the seams and analyses of outcrop samples are to be given considerable allowance for effects of landslipping, saturation with water, etc.

Drill hole No. 11 D is the lowest hole topographically, 14 feet above sea level, in these lower measures, and it showed two seams 4 feet 10 inches and 4 feet 4 inches thick, respectively, the former at a depth of 15 feet and the latter at 60 feet, the intervening rock being arenaceous shale. Though the boring is 112 feet deep it does not reach the lower limestone.

Drill hole No. 13, a trifle over 200 feet distant along the line A D (see vicinity map, Pl. VI), shows eleven seams, the thickest being 4 feet 11 inches. Now with which seams of No. 13 to correlate those of No. 11 D is one of the most puzzling problems encountered anywhere on the island. By making use of three drill holes not in the same plane the dip can be determined when any one bed which is constant and distinct enough to be used occurs in each bore. By projecting this stratum in each hole up to the plane in which it is found in any one, taking either the highest or lowest point of the stratum as the plane of reference (it is immaterial which is taken), the dip is readily computed. But when there is no one bed distinctive and constant enough to tie to there is difficulty right away, and this is just the trouble in many of the bore-hole sections of Batan Island. From the irregularity and almost total discordance between many of the bore holes close together it would seem that violent disturbances had taken place, or that the coal had pinched out, thickened and thinned many times, but it is believed that the case is not really as bad as it at first appears. The writer is more of the opinion that difficulties in the drilling, casing, inability to obtain cores of all the strata passed through, and lack of care and knowledge on the part of the drill men may be made to explain a great deal of the apparent discrepancy. In fact, the writer on examining the drill cores found one or two cases of mislabeling.

If the dip between these holes can not be satisfactorily determined we still have some idea of what the dip should be from observations made in the small prospect entry in the rear of the commanding officer's house, where the 7-foot seam of drill hole No. 11 D was entered approximately along its strike. At this point it dips 65° north 70° west. There seems to be no question but that this seam is found again in No. 11 D, where two seams occur, the upper of which is 4 feet 10 inches and the lower 4 feet 4 inches. The former of these two corresponds to the upper one in the tunnel, the latter to the seam penetrated by the cross cut eastward at approximately 30 feet from the main tunnel. Of course there necessarily must be a radical change in the angle, a flattening out of the beds, to make these check up at all. The state of things here is about as represented in fig. 7, page 37.

The coal found in these bore holes and the prospect tunnel has shown up well in both the analyses and calorific tests. Reference is invited to Table III. However, the seam in the prospect entry shows up some not altogether favorable features. Below is a sketch of actual conditions of the face on March 30, 1905:

From day to day as the work progressed the face was watched closely, and the shale partings, "butter," were seen to thicken and thin and sometimes disappear, but always come in again. This, of course, if a persistent phenomenon, would militate seriously in the mining of the coal.

Clearly from the high northwest dip on the west side of the igneous outcrop, the slicken-sided and broken appearance of the coal, and the southeast dip, found in the stream bed 220 yards east of the outcrop toward Tinicauan, we may argue the presence of an anticline. The apex would be well up on the side of the ridge, not at the top, for we are dealing with the lower beds.

The coal in the upper or middle horizon shows up better in the writer's opinion than that in either of the other sets. Three seams have been penetrated in a number of places by drill holes and entered by means of seven prospect tunnels, the two most important being that known as the "Urgera mine" on the old Spanish claim of the same name, at an elevation of 210 feet; and the San Francisco, or "Big Tree" seam, at

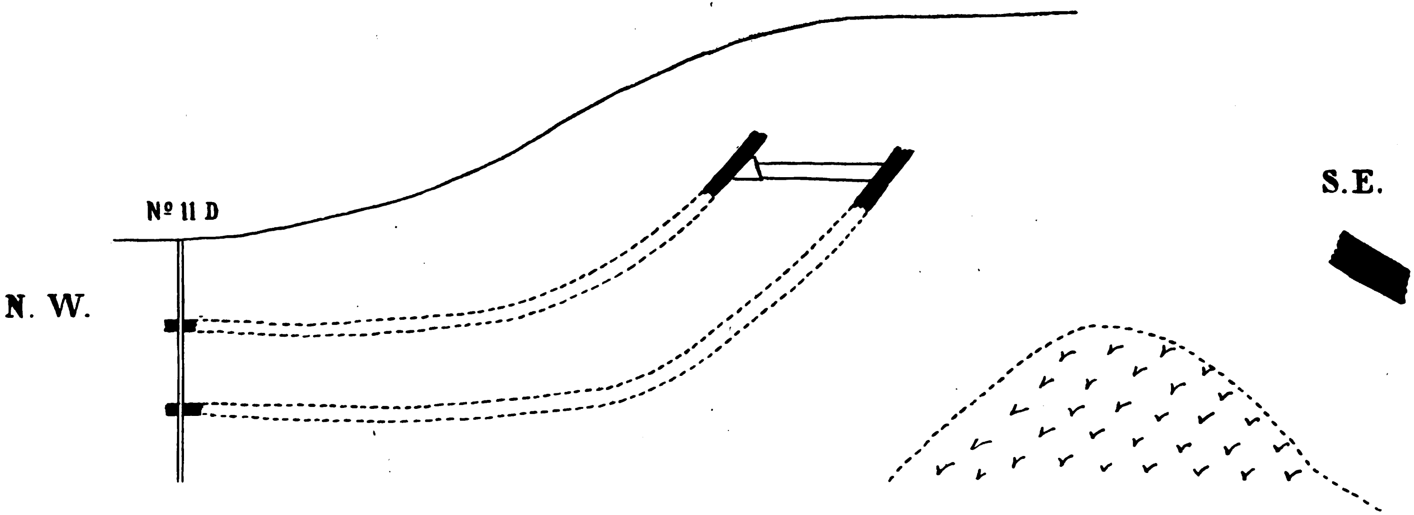

FIG. 7.—Diagram section near commanding officer's house.

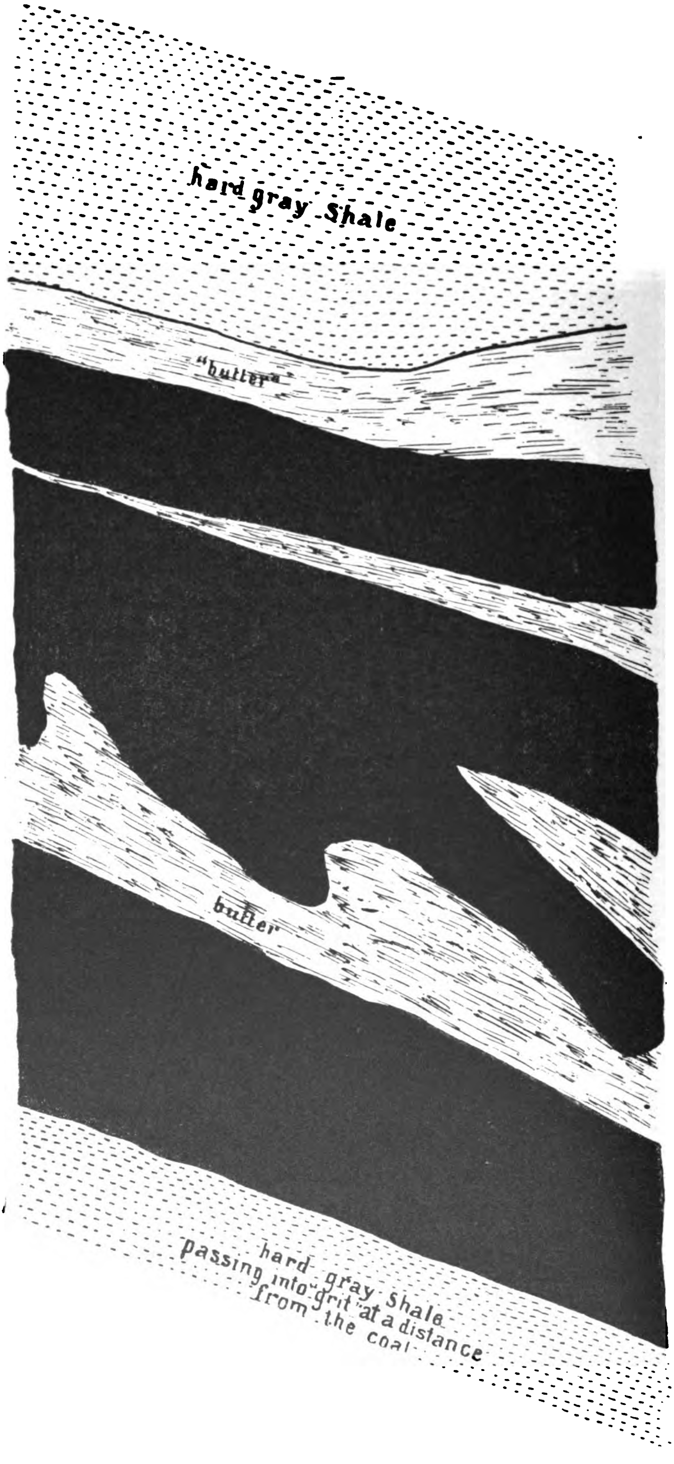

FIG. 8.—Sketch of face of coal seam in prospect entry, Liguan.

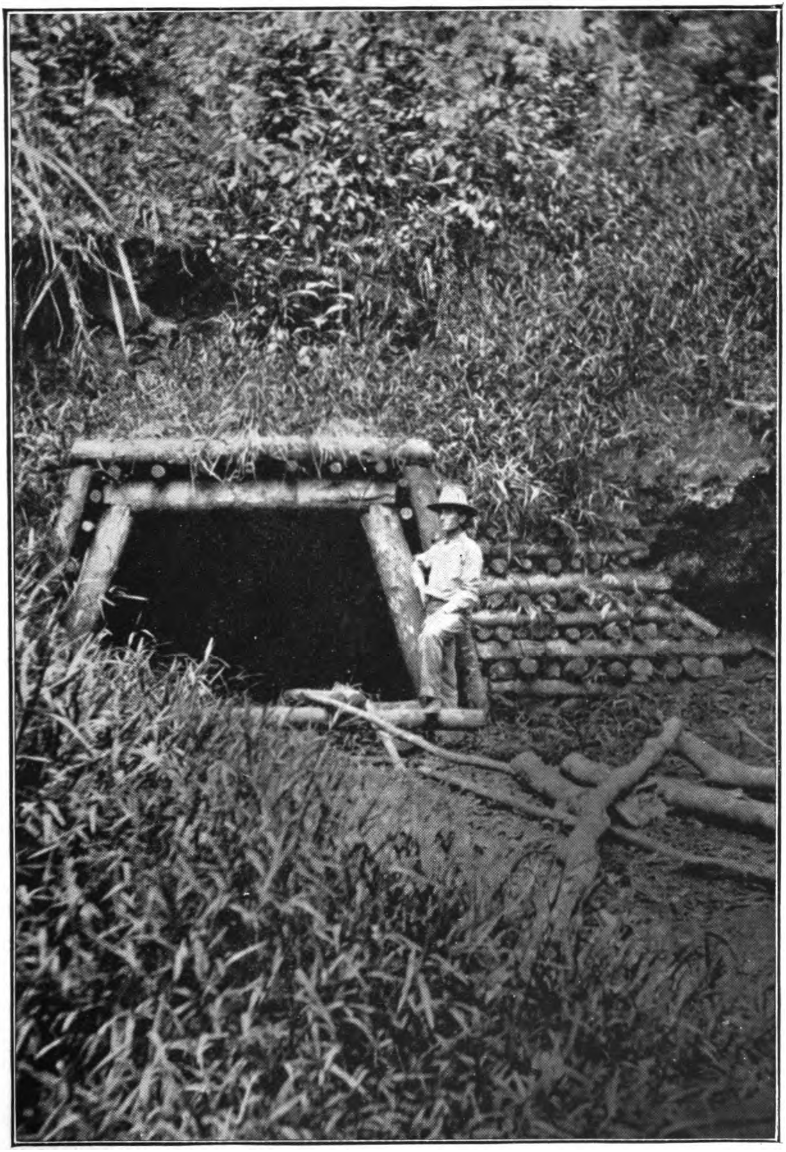

PLATE VIII. "BIG TREE" SEAM, SAN FRANCISCO MINE.

a height above sea level of 374 feet. From a careful examination of the stratigraphic relations obtaining at these two workings the seams in the Urgera workings are to be correlated with those in the San Francisco tunnel, both workings being located more nearly on the line of strike rather than along the line of dip. In the "Big Tree" the dip is 20° to 25° north, 15° to 25° west, while in the Urgera it has swung around more to the east, being north 40° east, with an angle of 10° to 15°. Both coal beds have shale or fire-clay floors and a bed of coarse to gritty sandstone overlying. The coal in the two localities is very much the same, with the odds somewhat in favor of the "Big Tree" outcrop. In the "Big Tree" the coal held up to a thickness of 6½ feet for 30 feet when it pinched out, the roof running down to meet the floor, and not vice versa. This is very important, for it shows us that the formation is not a lenticular one but, it is believed, merely a local "want." Lieutenant Wigmore thought it an old stream channel later filled with débris. The writer was unable to get far enough into the abandoned working to judge for himself. The purely local character of this "want" is made evident by the fact that in another entry in the same seam only a few feet away nothing of this character was seen at all.

The Urgera tunnel showed a total of 14 feet of coal, which great thickness is attributed to the "bunching up" along the crest of an anticline. But here again a fault was found, having a south 80° east direction and a hade of 10° (already referred to above).

Both these coals possess a good face cleat which would be of advantage in mining, and they have fair adhesiveness and but little sulphur. Analyses of these coals are given in Table III, showing their favorable comparison with Japan, Wyoming, and British Columbia coals which are of the same class.

Plates XVI, XVII, and XVIII show sections along the lines A–D, A–B, and E–B, respectively, on Plate VII.

BILBAO AND CHIFLADURA PROPERTIES.

The seam most extensively worked at the Chifladura and Bilbao properties is one outcropping at the 25-foot contour line on the former property and on the 100-foot contour on the latter. At Calanaga the seam is 3 feet 5 inches thick, having a hard, dark shale floor and with a firm roof requiring little timbering, with a dip of the whole of 20° north 32° east. The coal is, however, quite inferior to the Liguan coal in that it comes very near to being a typical lignite, has very appreciable quantities of resin, iron pyrites (which, of course, means sulphur), and shows a very decided tendency to crumble into little irregular cubes. But the worst feature of all is the ease with which it takes fire from spontaneous combustion. The old Bilbao working on the west side of Calanaga Bay had to be abandoned on account of fire in the mine which started from no explosion but simply from spontaneous combustion.

According to Professor Lewes[1] and others considered to be the ablest authorities on the subject of fires, explosions, etc., in mines, the causes of the spontaneous combustion of coal are: "First, and chiefly, the condensation and absorption of oxygen from the air by the coal, which itself causes heating, and this promotes the chemical combination the volatile hydrocarbon in the coal and some of the carbon itself wi the condensed oxygen. This process may be described as self-stimul ing, so that, with conditions favorable, sufficient heat may be generat to cause the ignition of portions of the coal. The favorable conditio are: A moderately high external temperature; a broken condition of t coal, affording fresh surfaces for absorbing oxygen; a supply of a sufficient for the purpose but not in the nature of a strong curre adequate to remove the heat; a considerable percentage of volatile co bustible matter or an extremely divided condition. Second, moistu acting on sulphur in the form of iron pyrites. The heating effect o this second cause is very small, and it acts rather by breaking the co and presenting fresh surfaces for the absorption of oxygen."

The conditions found at both the Bilbao and the Calanaga workin seem to be almost precisely those outlined by Professor Lewes. Whe last visited by the writer the coal dump beneath the camarine at th Chifladura mine was on fire.

Nevertheless this coal has been used on small coastwise vessels for number of years with fairly satisfactory results. In Table III is a analysis of the Bilbao coal. It is seen, at once, to be high in sulphur— more than would be good for boilers—contains over 12 per cent o moisture and 7 per cent of ash, and it is neither very high in fixed carbo nor in volatile matter. Its fuel ratio is less than 1. The analysis o the Chifladura coal has not been completed yet, but it is not expected to show up materially different. The question of fuel ratio, steaming values, and kindred points will come up for further discussion in the section on value and classification of the Batan coal.

A prospect entry located at an elevation of 10 feet above high tide, on the Bilbao property, near the company's office, was run into the hillside for a few feet to investigate an outcropping of another and lower seam. This had entirely caved in before the writer's visit and only the remains of the dump outside could be seen. Examination of this brought to ligh pebbles of quartz and "grit," and fragments of the underlying igneou rock were picked up, which makes it quite possible that this sean corresponds to one of the lower Liguan seams. Neither the dip nor th thickness of the seam could be ascertained.

At the time of Lieutenant Markham's visit and later during the writer visit, in 1905, to the Bilbao property, there was no possibility of gettin

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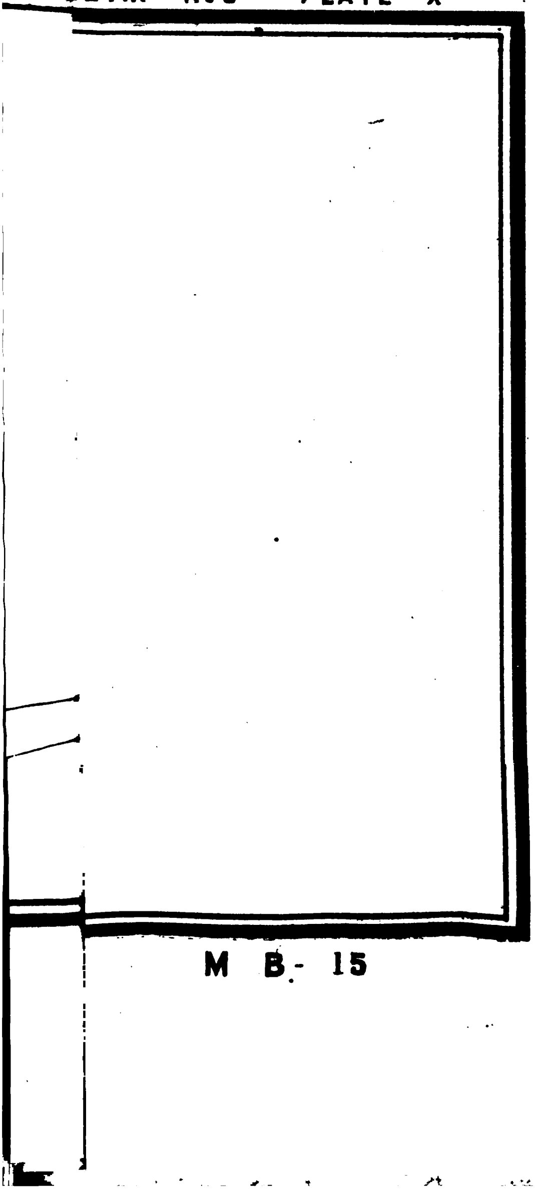
[1] *The coal and metal miner's Pocket-book*, 7th ed., Scranton, Pa., 1902, p. 291.

D. M
ETIN No 5 PLATE X



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into the workings, as all the entries had caved in; so that we are obliged to rely largely upon the company's prospectus, which, of course, is never a satisfactory thing to do. From the prospectus of the "Minas de Batan" company (Gil Brothers) we quote all that was known up to the time Lieutenant Markham's reconnoissance was made. As the latter was at the same time making a general survey of all the localities in the Islands known to contain coal, for the military government, the information he could obtain in the short time at his disposal is somewhat meager.

To quote the prospectus:

> There are seven veins explored up to the present time. They are nearly parallel to each other, with an average thickness of 1 meter and an inclination of approximately 25.° The workings are: Gallery No. 1, running in a direction of north 20° west, transversely to the first vein, which is cut at 25 meters' distance from the point of excavation. At this point a gallery following the vein has been opened, this gallery being worked for a distance of 23 meters in length. The transversal excavation continues, encountering the second vein nearly parallel to the first and 35 meters distant; this has been worked for 32 meters. And for vein No. 3 two galleries, Nos. 2 and 3, have been opened, situated at an elevation of 35 meters above No. 1, and both in a longitudinal sense, No. 2 being found at 10 meters' elevation with a thickness of 1.1 meters and an inclination of 20° west. The other labors are prospects for investigation, and all of them promise a large quantity of coal.

The total length of these galleries was about 125 meters.

According to the notes of Mr. Halvorsen, the Bilbao mine was opened in November, 1903, by Japanese miners under the supervision of Mr. Gato, also a Japanese, at the site shown on Plate X, where they entered only one seam and made three different adits. It should be said, before proceeding further, that previous to this, in 1899, some Spaniards started in, but all got drunk and were discharged. In 1903 camarines, offices, tramway, and a small plant were all erected and quite a prosperous community grew up in this quiet recess in the jungle. They had removed about 500 tons of coal, transporting it in small barges at high tide down the sluggish Calanaga River (hardly deserving the name), when fire broke out and so completely discouraged the company that it moved across to the eastern side of the bay to the Chifladura claim, where work was begun anew.

BATAN.

On Plate XI are shown three entries in the coal seams which outcrop on the hillside just south of the barrio of Batan. Here the coal is exposed in two seams with a parting of fire clay between, as follows:

	Feet.
Carbonaceous shale	0.4
Coal	.9
Gray fire clay	.5
Coal	3.7

Gray shale or fire clay at bottom.

These seams dip 13° in a direction north 1° west.

In general appearance this coal is not much different from the Calanaga Bay coals. It has a conchoidal fracture and portions of it resemble rather closely cannel coal. The beds appear to be less disturbed here than in any portion of the island. The natives had tunneled in about 60 feet and had used no timber.

These seams are found outcropping farther around the hill to the west, where they have been opened up for a few feet.

In the reddish-gray shale above in coal beds numerous small pelecypods, Tellinas, Mactras, etc., were found.

This coal shows little or no resin, and possesses a good cleat parallel to the face of the seam. Doubtless it could be easily mined.

PRESENT METHODS OF MINING.

The small large-scale maps and plans (Pls. VIII, IX, X) show all the surface plants and plans of underground workings of the three eastern localities.

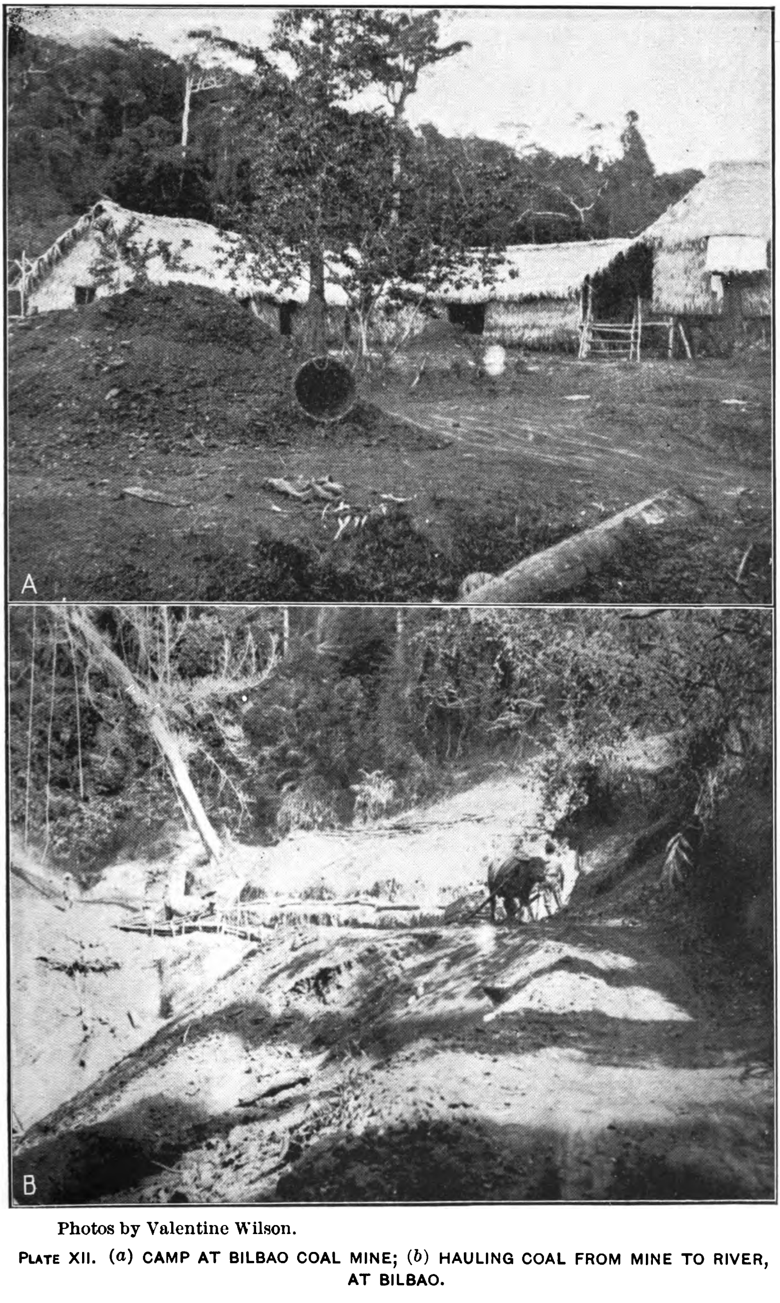
The method of working was very primitive both at the Bilbao mine and at the Chifladura and was never planned, it seems, with a view to the future. The Japanese miners used no explosives and dislodged the coal by undercutting with their own peculiar hand picks, transporting it out on their backs up the steep incline of the tunnel. As there is a 4-inch clay parting about midway in the seam they would first work out the coal from below the parting, remove the parting and leaving it in the mine, and then cut down the remainder of the coal from the roof. Mining here and at the Chifladura was always to the dip. This necessitated pumping, and when the writer was at the Chifladura great inconvenience was experienced through lack of a good pump. About 80 per cent of the coal was removed by this method of mining.

Very little timber was used save in the main tunnels, and when it commenced to become unsafe the whole mine was abandoned and a new tunnel started. On our last visit to this mine all the timbering had given way and a desolateness pervaded the whole place, which had been so thriving not two years before. Mine timbering in the Tropics will always be a serious proposition.

When the work was resumed at the Chifladura in October, 1904, Mr. Ikeda had charge of the work. His method of mining is about the same as that of his predecessor, but his timbering, we believe, much better.

COSTS OF MINING.

The following figures were obtained from the Japanese contractor, Mr. Ikeda, and not from the company's records. The work was piecework, the miners being paid 60 cents, Philippine currency, per ton, if explosives were used, but 40 cents, Philippine currency, extra if not used,



Photos by Valentine Wilson.

PLATE XII. (*a*) CAMP AT BILBAO COAL MINE; (*b*) HAULING COAL FROM MINE TO RIVER, AT BILBAO.

Photo by Valentine Wilson.

PLATE XIII. DRIFT AT BILBAO MINE.

making ₱1 per ton. Below is a list of the men employed and their remuneration:

Number.	Class of labor.	Rate of pay.
1	Contractor .... per month..	₱100.00
1	Carpenter .... do....	90.00
1	Blacksmith .... do....	75.00
1	Foreman .... do.....	60.00
12	Miners .... per ton..	1.00
4	Filipinos (outside work) .... per day..	1.00
1	Laborer (for repairing) .... do....	1.80

The contractor also received ₱2.20 a ton for all the coal at the mine mouth or ₱2.50 for it placed on the dock. The timbering was paid for by the company. Taking into consideration the cost of the tramway, the salaries of the foreman, carpenter, blacksmith, clerk, and overseer of the camarine where the coal is stored, the cost of the camarine (said to be ₱6,000), building of a dock and other buildings of the plant, Mr. Ikeda estimates the total cost per ton at ₱4, sometimes as high as ₱5.

The company, which is a Spanish organization for the most part, is said to be capitalized at ₱1,000,000, which is distributed in 1,000 shares. It owns one small steamer of 2,700 tons, called *Minas de Batan,* which transports the larger part of its coal. Other boats, like the launch *Evening Star,* coal here regularly, or did before the mine was closed down. The output per day was on the average of 22 tons, work being done in two ten-hour shifts, but a much greater output was looked for as they had just opened a new and more promising entry. This coal sold in some cases at ₱8 (f. o. b.) in the bay of Calanaga.

At present freight rates from Legaspi to Manila are $3, United States currency, per ton, proportionately greater than those charged between San Francisco and Manila. However, these exhorbitant rates must soon be reduced. Adding this rate to the cost per ton of mining under improved methods on a businesslike scale the coal could still be obtained at a lower figure than the lowest-priced Japanese coal, which is quoted at Manila in 1905 at $6.43, gold. Australian coal is somewhat less, being $5.79. These figures, which were obtained from the Insular Purchasing Agent, include the 10 per cent for expenses of handling.

Of course, a certain quantity of high-grade coal, such as Pocahontas, will be needed, for various uses, which will probably have to be imported for an indefinite period.

This question of cost, as far as it concerns mining operation carried on by the Army and Navy, has already received full and comprehensive treatment at the hands of Lieutenant Wigmore in his report to the Adjutant-General, a few words of which we quote here, as they will possess a general interest for the mining public. He says:

> With a modern mining and coal-loading plant in operation at this station, coal may be placed on board ships at docks (Batan Island) at $2 per ton. (A liberal estimate, covering all costs, which it is believed will be much below this figure.)

We have on the other hand some exact figures taken from Mr. Chas. E. Heurteau, writing in Annales des Mines (1904), of the costs of mining, etc., of Japanese coal.

> Coal from the Chikuko Basin (Island of Kiuskin), put on board at Moji, costs as follows: Mining, $1.43; transportation, $0.48; loading from bins to ship, $0.19; total, $2.10.
>
> * * * * * * *
>
> A man will mine by hand 2.3 tons daily in a seam 3 feet and 11 inches in thickness, while in beds 5 feet 4 inches thick he will pick 2.6 tons. The price per ton varies from 20 cents to 25 cents, according to the bed and the coal. Picking, hauling, loading, and timbering are included in this price. At Miike, where the bed is large and no timbering is done, it sometimes falls as low as 13 cents. * * *

From this it is seen that a 4-foot seam can be profitably worked under similar conditions to those which prevail in the Philippines, there being a great similarity in the structural geology of the two countries; also that the nearer the seam comes to 6 feet in thickness the better. And we may add that in general beds much over 6 feet can not be so profitably worked.

EXPLORATORY WORK ON MILITARY RESERVATION.

On the military reservation of the island little real mining was carried on, merely enough to get out quantities suitable for steaming tests. The work was nearly all confined to prospecting with diamond drills. Two drills were used, one a Bravo hand-power drill, with a small bit giving a 1-inch core, the other a Standard diamond drill with a 2-inch core. A Davis Calyx drill was ordered, but came out incomplete and could not be used. Twenty-three borings in all were made, as indicated on the large map, in the vicinity of Liguan, with the results already discussed in preceding pages. The cost of drill work was increased by many factors, among them being the rugged nature of the country, lack of water, the impenetrable forests, and the necessity of depending entirely upon carabaos for transportation. The cost per foot varied between $1, gold, and $5, depending upon distance to which machinery had to be transported, accidents in casing, loss of diamonds, etc. As Lieutenant Wigmore will shortly publish some figures in detail with reference to this work in Batan Island in one of the technical journals in the United States, we forego any further discussion of this feature.

Plate XV shows a plat of the San Francisco mine, the most extensive bit of underground work on the military reservation.

CLASSIFICATION OF BATAN COALS.

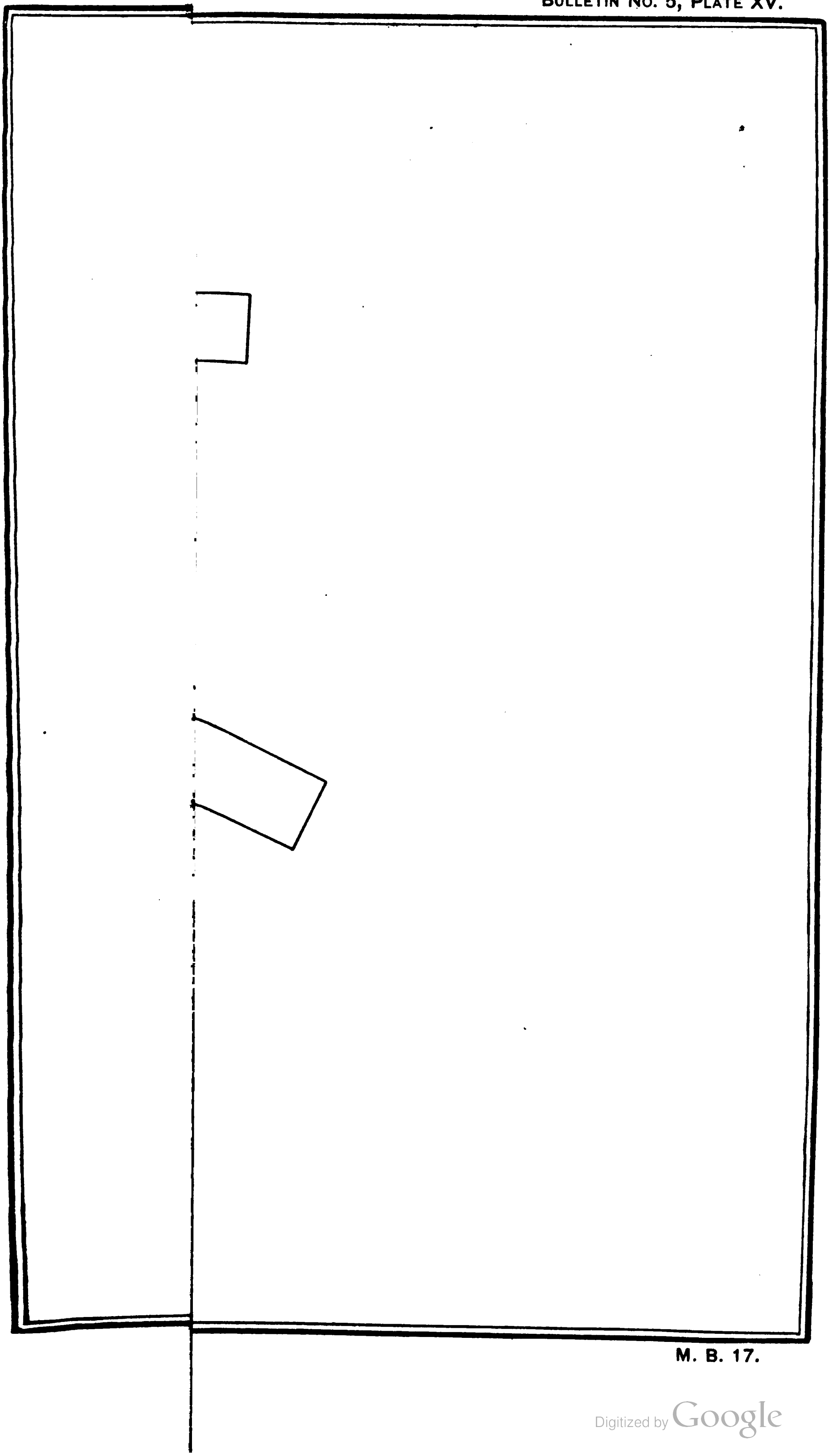
As there appears to be no little confusion and ignorance in the minds of many with reference to the proper classification of our Philippine coals, it has been deemed advisable to outline the differences between bituminous and lignite coal, and then to place our coals in their proper

Photo by Valentine Wilson.

PLATE XIV. PROSPECT HOLE AT LIGUAN.

THE MININ

BULLETIN No. 5, PLATE XV.



M. B. 17.

category. Because the coals are found in Tertiary strata is no reason for calling them lignites any more than it is scientific to class all crystalline schists as Pre-Cambrian. It is true, however, that a coal as young as the Tertiary is more liable to be lignitic than bituminous or anthracitic.

Many divers criteria have been laid down for the distinction, but there seem to be three which are, according to Mr. Collier, of the United States Geological Survey, to be taken as most reliable. It may be said here that this same question came up in connection with Alaskan coals, and Mr. Collier and Dr. Hayes gave it considerable attention in Bulletin 218, United States Geological Survey, "On the Coal Resources of the Yukon, Alaska."

First is the fuel ratio; second, content of water; and third, physical character of the coal, woody structure or otherwise. The fuel ratio is obtained by dividing the percentage of fixed carbon by that of volatile matter. If the quotient be more than 1, according to the above authority, the coal should be classed as bituminous; if less than 1, as lignite. Practically this is the most important criterion, but logically the possession of woody structure is the most important, for that is what was in the mind of the man who first used the term "lignite;" the term means "woody." It would seem that some one had strayed from the original premise. Still the other distinctions have grown up and so demand attention.

The second criterion is the water content. If the coal contains over 10 per cent, they say it is a lignite; but what has this to do with the term lignite? Still another criterion is the percentage of fixed carbon and that of volatile matter. According to Kemp, when the percentage of volatile matter is over 50, the coal is a lignite.

Grüner's classification, based on the ultimate analysis of the coal and the ratio of $\frac{O+N}{H}$, is also important, but owing to the analysis not being completed we shall have to forego consideration of it at this time.

To further simplify matters, Mr. Collier has made use of what he calls the lignite ratio, which is the quotient obtained by dividing the water content by the fuel ratio. When this is less than 10, the coal is to be classed in the bituminous series; if more than 10, with the lignites. By inspection of Table III we can quickly classify our various coals. It will be seen that the analyses following No. 26 all correspond to those of true lignites, but as many of these are of coals from outcrops and prospect tunnels not over 50 feet in from the surface they will necessarily be less reliable than those of samples from the same seam if they could be taken from points more deeply buried. Numbers 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 25, and 26 in Lieutenant Wigmore's series are all to be classed as bituminous coals, according to every criterion. The Bilbao coal, No. 6–55 in the table, must, in all probability, be classed as a true lignite. Samples from the Chifladura mine differ very little from those of the Bilbao coal, as they would be expec do, being from the same seams in all likelihood.

The third criterion can be easily applied, and we have examined i connection thin sections of both the Batan and the Liguan coals. former does show in the upper and exposed beds a woody structur the Liguan coals do not—no trace of it.

VALUE OF BATAN COALS.

Table II has been compiled with a view to giving an idea of how coals compare in analysis and calorific power with other Philippine and many representative and well-known foreign coals that are sold in the Manila market.

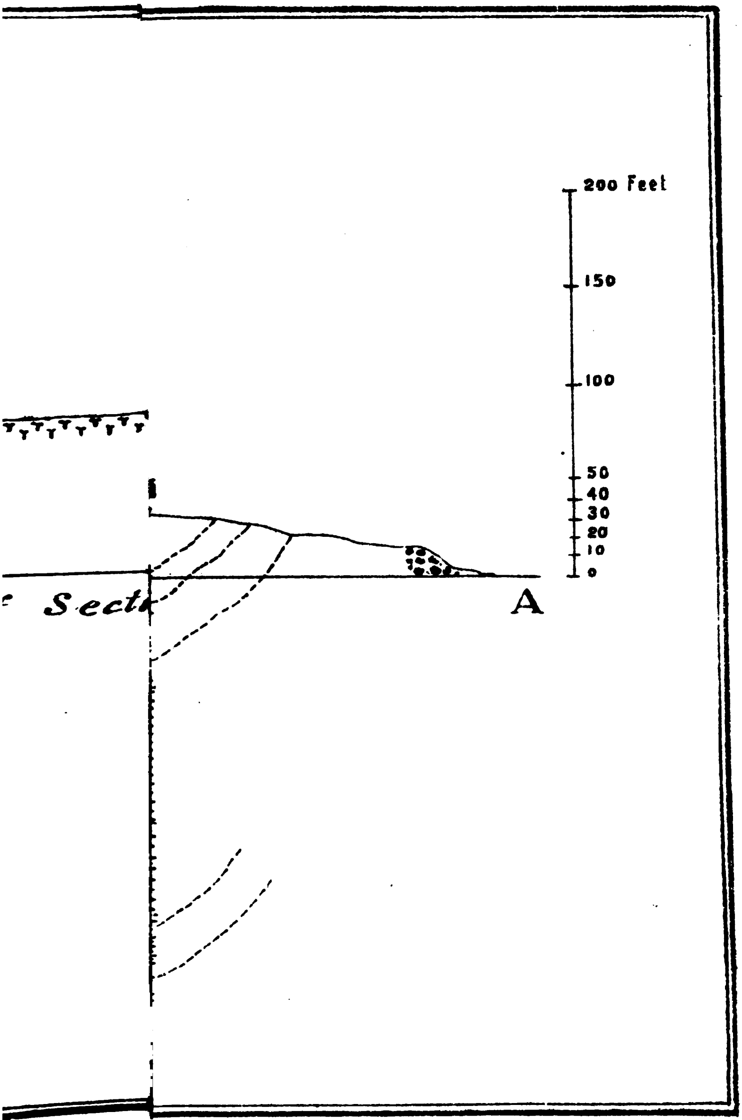
It is clearly seen that there is coal on Batan Island, and in many p in the Islands, which compares most favorably with many coals whic used for steaming at sea and on land. In fact, the coal used b engines that draw the Southern Pacific trains over the Sierra Ne Mountains is not superior in any respect to our best Batan coal. statement the writer feels fully justified in making from comparis the analyses and the hand specimens, both of which are on his de the time of writing. In fact, Mr. Burt, ex-president of the U Pacific Railroad, when shown samples of the two, said that the B coals appear equally as good as their "U. P. No. 1." And not onl the Batan coals compare so favorably, but so do samples from C and from the Island of Polillo, whose analyses and calorific power included in the table.

It is seen from Table III that none of the Batan Island coals yielded a coke. This is of course a serious objection when it come finding a coal here suitable for blast-furnace work. Still a coking may yet be discovered in this vicinity, as this coal shows incipient cok Indeed, Mr. H. D. McCaskey, Chief of this Bureau, tells me he obtai a very fair coke from samples supposed to be of this coal, when exp menting about four years ago.

Of the quantity there can be no question. The tonnage per foot thickness per acre for bituminous coal is generally estimated at 1,5 and as there are several square miles of surface on Batan Island, say nothing of the other localities underlain in all probability by c seams, 3 and 4 feet thick at least, it does not take very much figuring settle this point.

For the benefit of the general public and the mechanical engine especially, to both of whom the following may not be accessible, we inse coal efficiency reports furnished through the courtesy of the milita secretary. These are reports from the chief engineers respectively of t U. S. C. T. *Chukong,* U. S. A. T. *Sacramento,* and the U. S. C. *Palawan.*

BULLETIN No 5 PLATE XVII



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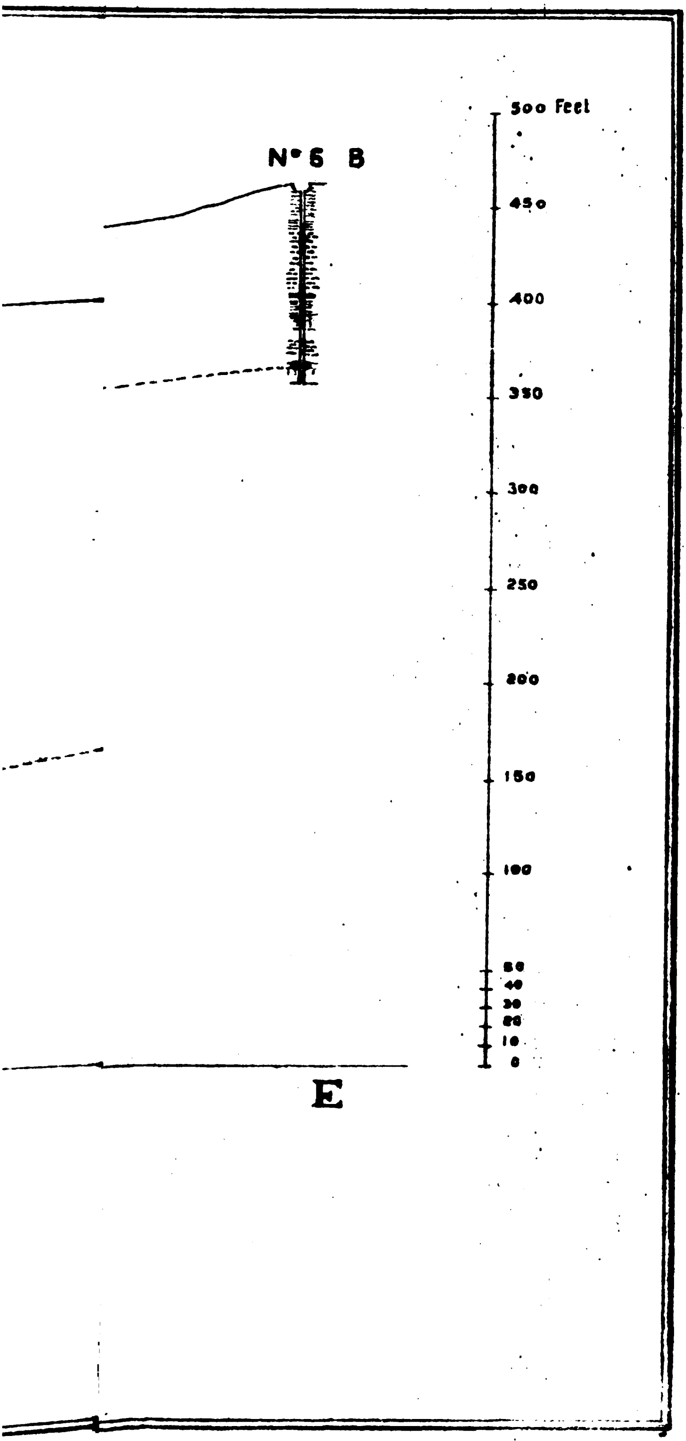
BULLETIN No5 PLATE XVIII



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COAL EFFICIENCY REPORTS.

[**War** Department, Army Transport Service. U. S. A. T. *Chukong;* date of coaling, May 21, 1904.]

1. Trade name of coal: Batan.
2. Where received: Manila.
3. From whom procured: Quartermaster Department.
4. Price per ton: (Not given.)
5. General appearance as to lump, slack, and impurities, and percentage of lump: Fairly lumpy, 50 per cent.
6. How long stored at place where procured: Do not know.
7. From under cover or not: Do not know.
8. Was the coal dry, damp, or wet when stowed? Do not know.
9. Length of trial reported on: Sixty hours.
10. Condition of boilers in use: Good.
11. Tried with forced or natural draft: Natural draft.
12. Was the draft good, fair, or poor? Good.
13. Area of grate surface in use: 33 square feet.
14. Per cent of refuse (weighed dry): 5.24 per cent.
15. Were the clinkers large in size or quantity? Quantity.
16. Was the work at the fires excessive on account of their being dirty? No.
17. Was the soot formed excessive in quantity? No.
18. How often necessary to sweep tubes? Once in sixty hours.
19. Is this coal suited for forced draft? Yes.
20. Any undue heating of smokepipes or uptakes? No.
21. Was the smoke dense, or dark in color, or easily dissipated? Easily dissipated.
22. Pounds of coal consumed per hour: 580.
23. Knots made per ton of coal consumed for all purposes: 33 knots.
24. Average indicated horsepower of main engines: 200.
25. Estimated horsepower auxiliaries in use: 10.
26. Pounds of coal consumed per horsepower (total main and auxiliary) per hour: 1.45 pounds.
27. Revolutions of main engines per minute: 200.
28. Average speed in knots per hour: 8½ knots.
29. How long ship out of dock? Nine and one-half months.
30. Condition of ship's bottom: Fairly dirty.
31. Estimated effect in knots per hour of wind, sea, and sails, upon speed: Increased —— knots, decreased —— knots.

REMARKS.—Excellent. I can recommend this coal to the following extent: As being a first-class steaming coal, and with a small percentage of ash; also only having to clean fires once every eight hours.

SIDNEY S. MILLS,
Chief Engineer Transport.

[Report from Chief Engineer Dickinson, of the *Sacramento.*]

First. With reference to Japanese coal:

(*a*) Weight of coal used in getting up steam to the usual steaming pressure; for example, 110 pounds from cold water: 640 pounds.

(*b*) Time of getting up steam as above: Eight hours.

(*c*) Weight of ash from coal burned as above: 134.5 pounds.

(*d*) Weight of coal burned in six hours steady steaming under the usual steaming pressure; for example, 110 pounds: 4,236⅜ pounds.

(*e*) Weight of ash from coal so burned: 889.56 pounds.

Second. With reference to Batan coal:

(*a*) Weight of coal used in getting up steam to the usual steaming pressure; for example, 110 pounds from cold water: 530 pounds.

(*b*) Time of getting up steam as above: Seven and five-tenths hours.

(*c*) Weight of ash from coal burned as above: 31.8 pounds.

(*d*) Weight of coal burned in six hours steady steaming under the usual steaming pressure; for example, 110 pounds: 3,570 pounds.

(*e*) Weight of ash from coal so burned: 676 pounds.

Third: (*a*) Horsepower and number of boilers and grate area of same: Boilers, 2; indicated horsepower, 212.48; 45 square feet.

(*b*) Relative quantity of soot given off by the two coals: Japanese, 10 per cent; new coal, 2 per cent.

(*c*) Relative amount of smoke and colors of same: Very little smoke, and very light.

(*d*) Whether clinkers are found in Batan coal; and if so, relative amount of same: None.

(*e*) Does Batan coal necessitate more or less frequent cleaning of tubes than Japanese coal? Less.

(*f*) What kind of firing gives the best results—light and frequent, or in large quantities at long intervals? Just average fires; say, 4-inch fire.

The Batan coal is far superior to the Japanese coal in every respect. On a trial of sixteen hours there was no soot to speak of, and it gives fine heat and there are no clinkers at all. It burns well; the ash and refuse are very light. It is by far the best coal I have used in the Philippines. It is excellent.

Respectfully submitted.

J. P. DICKINSON,
Chief Engineer Sacramento.

[Report from Chief Engineer Beach, of the *Palawan*.]

Weight of coal used in getting up steam to the usual steaming pressure from cold water: We were under steam pressure all the time we had Batan coal on board.

Weight of Batan coal burned in sixteen hours steady steaming was 12,800 pounds. We carried 110 pounds pressure and steamed 8.5 knots per hour.

Weight of ashes and clinkers from the above Batan coal burned in sixteen hours was 1,554 pounds.

Weight of coal (Japanese or Australian) burned in sixteen hours steady steaming was 9,200 pounds.

Steam pressure carried was 110 pounds; knots steamed per hour, 8.5.

Weight of ashes and clinkers of the above coal was 1,870 pounds.

The horsepower of boiler is about 550; grate area, 55.5 feet; number of boilers, 1.

Soot from the Batan coal is lighter in color and only one-third as much as that from coal we have been using.

The smoke is of a light brown, not so dense as the coal we have been using.

There are no clinkers formed in the Batan coal.

The boiler tubes will run much longer than with the coal we have been using.

I found that firing heavy and at long intervals was the best.

Total Batan coal used, 62,980 pounds; 52,200 was used while steaming, 10,780 was used in banked fires.

Total amount of ashes was 7,017 pounds, or 11 per cent.

Total time under way with Batan coal, sixty hours and seventeen minutes.

One item in particular should be noted, namely, the proportionate amounts of Batan and Japanese coal required in given number of hours steaming. Chief Engineer Beach, of the *Palawan,* estimates that in sixteen hours steady steaming 12,800 pounds of Batan coal were used against only 9,200 pounds of Japanese or Australian coal. We suspect that this latter coal was Australian and not Japanese, for Chief Engineer Dickinson, of the *Sacramento,* reports in a six-hour steady steaming test he used 4,236⅔ pounds of Japanese coal against only 3,570 pounds of Batan coal required.

To be obliged to carry nearly a third (28.8 per cent) more coal in the ship's bunkers for a given number of hours steaming than required by another coal, of course, is an immensely important item.

The reason for the greater consumption of Batan coal in the same number of hours of steaming over that of Japanese coal must be looked for in the difference in water content of the two coals. Theoretically the Batan coals have a higher percentage of fuel value, as seen by taking the sums of the fixed carbon and volatile matter in each case and comparing them. We are comparing now the Batan coals with Japanese coals sold in Manila, not with the best Japanese coals, which do not come here.

This fact gives us some encouragement, for the Batan coals hitherto have come from the surface or very close to it, while the Japanese coals are mined from considerable depths, where we should expect the coals to possess little water.

On the other hand, it should be noted in favor of the Batan coal that it leaves very little ashes and clinkers as compared with Japanese and Australian coals.

Now comes the question, Can the coal be mined economically? This is the crux of the matter. In the writer's unbiased opinion, unless further drilling and tunneling show the coal seams to be more uniform and continuous, there will be no little difficulty in mining. However, every other feature of Batan Island is favorable and the coal-bearing strata are in general continuous over the large part of the island.

To show that coal seams thinner than the Liguan seams possessing numerous faults and inferior analyses can be worked profitably, we can find numerous examples in Japan. From "Outlines of Geology of Japan"[1] we quote:

> The coal seams (Province of Hizen) are generally thin (7 and 3 feet), but they are profitably worked in numerous places on account of their good quality and the convenience of transportation.

Analysis of a Hizen coal is as follows:

	Per cent.
Moisture	0. 98
Fixed carbon	53. 42
Volatile combustible	39. 08
Ash	6. 53
Sulphur	. 65
Specific gravity	1. 27

In the Ishikari field faults are frequent.

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[1] "Outlines of Geology of Japan," p. 204. *Geological Survey of Japan,* 1902, Tokyo.

Still the field of Batan has not been as systematically prospected with drills by any means as it should be, and the writer can unhesitatingly say that it is worthy of further exploration under the personal and constant direction of an especially trained engineer experienced in coal-field work. Such an engineer, then, would take over the work of management of the mines and work to a greater advantage than if he had no part in the exploratory work that had gone before. And it is believed this is the idea that Lieutenant Wigmore himself entertains. A word here should be said in commendation of the work carried on by Lieutenant Wigmore, a work the first of its kind in the Philippine Archipelago. Though trained as an Army officer he has shown an unusual understanding of the importance of scientific geological work in connection with mining. The work he did has proved immensely valuable in spite of the many obstacles which he had to face.

One of the greatest needs for future exploratory work is at least one up-to-date diamond drill capable of penetrating at least 2,000 feet of strata, for besides being able to trace the deeper seams on the northern side of the island, much very valuable information would be at the disposal of the stratigrapher which would not appear at first sight particularly vital to the layman. The importance of accurate geological facts which the geologist ought to have at his command is absolutely necessary to modern mining work. The day of nuggets and the ignorant prospector is past, and many of the largest fortunes are being made from the working of low-grade deposits scientifically treated according to the principles of chemistry and physics, which are the principles of geology.

MARKET.

Whether there will ever be any appreciable exportation of coal from the Philippine Archipelago is an open question, but that most of the coal used in the Islands themselves will eventually come from one or all of the three fields—Batan, Polillo, and Cebu—seems quite probable.

With reference to the outside market we might very well give here some facts which will show at least the possibilities in this direction.

The apparent possible outside markets are Shanghai, Hongkong, and Singapore.

Hongkong imports 800,000 tons of Japanese coal, all from Moji, Kiusiu; paying for lump coal 7.75 to 8.50 and for run of mine 6 to 7 Hongkong dollars ($0.47, gold). The freight rate from Moji to Hongkong is 1.70, Hongkong currency ($0.799).

Hongkong also imports Australian coal, but unfortunately we have not the figures at hand. For this coal is paid 4.85 to 5.30, Hongkong currency.

Singapore imports in round numbers:

Class of coal.	Number of tons.	Cost.[1]	Ex wharf.[2]
Japanese	400,000	8.75 to 9.00	11.00 to 11.50
Australian	36,000	7.50?	10.50
Indian (Calcutta)	108,000	7.75	9.00
Borneo	7,000	8.00 to 8.50	10.00 to 10.75
Cardiff	42,968	12.00?	15.00

[1] Straits currency. [2] Cost, insurance, and freight.

The above figures are from a recent letter from Lieut. H. L. Wigmore.

With reference to the Indian coal, the chief engineer of the *China* (Pacific Mail Steamship Company) and the engineer of the *America Maru* both have called it a very dirty and unsatisfactory coal.

For the year 1903 the summary of imports [1] into the Philippine Islands is as follows:

Purchaser.	Tonnage.	Value.
United States Army (fiscal year)	141,490	$702,652
United States Navy (calendar year)	61,131	432,924
Civil Government (fiscal year)	32,626	
Total Government	235,247	
All others	157,801	472,891
Grand total	393,048	

Source and tonnage.

Japan	159,257
Australia	161,074
United States	72,156
Total	392,487
All others	561
Grand total	393,048

Another feature connected with mining in the Philippines is very important—that is, the question of labor. So far, the Igorots are the only natives found fit for mining work of any kind, and for some time to come it is believed that Japanese will have to be employed for the best results in coal mining. The Bicols of Albay Province as a rule show a great aversion to going underground, which, however, might be in time dispelled. Another characteristic of the native is his disinclination to work when he has a little money ahead. With a few pesos ahead he will usually leave his work for the nearest cockpit or wedding, and when he has spent it all he will come back. This is a trait inherent in his nature and is not entirely his own fault. The only way for the mine manager to offset this "costumbre" is to keep on hand about a third more men than he daily employs, for a reserve force.

But, in all fairness to the native and the whole labor problem of the Islands, we should state a few facts that afford a ray of hope. Mr. Lehlbach, who has employed a number of Igorots in Benguet in mining work, has expressed himself as well pleased with them. He also uses Japanese labor, which may account for his success with them. Visayans have proved fairly satisfactory in coal-mining work in Cebu. Mr. Graves, superintendent of electric lighting, city of Manila, has told the writer that he had been greatly surprised to find how good a workman the native made when put under competent and kind American bosses.

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[1] These figures are from Mr. O. Halvorson.

It is clear that we can not settle this question by one or two examples. As is the case the whole world over, a great deal, nearly all, depends upon local conditions, the men in charge, and the wages paid.

For more information on this subject and wage scales see Census of the Philippine Islands, 1903, Volume IV.

In conclusion, the writer would express himself as greatly hopeful for the future coal industry of the Islands. He sees many difficulties ahead for the operators, but none that can not be surmounted as they have been surmounted in Japan. With a great mining industry, and particularly in the black combustible, the dreams of centuries will be realized and Manila will truly become the trade and strategic center of the Far East.

Before concluding, however, a few words should be said relative to exploration. For the present, a brief statement as to where a diamond drill can be of the greatest service must suffice. First, a boring should be made in the valley of the Moncao River at the point lowest in the topography in order to pick up the coal seams in their northward extension. Second, one or two deep holes should be put down in the vicinity of the Government post to obtain information as to the depth of the igneous basement. Third, a drill should be set up in the valley of the Calanaga River at the lowest point in its topography in order to locate the lower horizons of the coal measures. And last, the San Francisco tunnel, the Urgera tunnel, and some new ones as well should be extended to find out if the coal seams resume their normal condition and position.

To prospective investors of capital in coal-mining work it may be proper to suggest that whatever work is attempted should not be projected on too great a scale and without thorough calculations as to costs and market first, or with too overflowing enthusiasm, as these were the causes of most of the Spanish failures. Further, the Polillo and Cebu fields should be looked over carefully before deciding on investment.

PRELIMINARY NOTES ON THE PALEONTOLOGY OF BATAN ISLAND.

During the progress of the economic work on Batan Island, collections, necessarily limited, of the fossil fauna and flora were made as well as a fairly complete representation of the living mollusca along the coast. The investigation upon these collections has been impeded by the writer's being absent from the office on field work part of the time since, and also through lack of reference literature.

But at this time it is possible to state a few facts which will throw some light on the stratigraphy and age of the sedimentaries of Batan.

First, the limestones are coralline from the lowest to the highest formation and the forms, imperfect as they all are, are seen to be almost identical with living species.

Species of the *Poritidæ, Astreidæ, Fungidæ,* and *Madreporidæ* are the most common.

The fossil reefs are fringed with living reefs. Only the outer part of the present reef is living.

As a rule the presence of coral in the limestone is only brought out by weathering.

In the bluish-gray limestone about 1 mile up the Caracaran River are many foraminiferal remains of which the tests of *Operculina complanata* and what strongly resembles *Cellepora formosensis* are the most abundant. Plate XX, *a* and *b,* shows sections in various directions through these.

Almost these identical forms have been described by Messrs. Newton and Holland from the "raised coral reefs" of Tokunoshima and Okinoyerabu on Riu-Kiu. These are considered by them indicative of the Post-Pliocene.

The writer has recently examined some sections of limestone from Baguio, submitted to him by his colleague, Mr. A. J. Eveland. In these are found sections of *Operculina complanata, Polystomella crispa?,* and *Textularia meyeriana?.*

These forms from Batan Island are not so large as those from Riu-Kiu, being on the average 1 millimeter in diameter, while some of those from Riu-Kiu attain a diameter of fully an inch.

There are also some sections of *Polystomella,* not unlike *P. crispa,* from the Pliocene at Sienna, Italy.

Again, on the east shore of Gaba Bay near the entrance, the shale was found to be very abundant in certain forms more like *Amphistegina* than any other genus.

With the foraminifera occur species of *Conus, Tellina, Dosinia,* etc.

The shales of the coal measures on the Persevarancia claim between Dapdap and Batan are very rich in apparently one species of *Tellina,* 15 millimeters long, and very triangular in shape. This form with others will be figured and described in a future paper devoted purely to paleontology.

An Arca very similar to *Arca diluvii* Lam. is also very common in many of the shales. In fact, *Arcas* are the commonest forms both as fossils and on the coasts to-day. The living *Arca,* however, is much larger than the fossil forms. Of the plant remains only one or two have been identified so far, both leaf impressions.

One is a species of *Laurophyllum,* very like *L. angustifolium* Newb. from the Amboy clays of New Jersey. It is roughly 5½ inches long by 1¾ inches across the widest portion of the leaf. Still another, about 3 inches long, resembles very closely some species of *Hymenea,* and some that are *Magnolias.*

It is expected that when all these forms are studied in connection with the present flora of the Philippines some interesting results will be obtained.

The above forms came from shale beds at the head of Caracaran River. The deposits are estuarine.

With this brief statement we shall leave this subject until time and opportunity allow us to carry on the investigation along the lines laid down by Mr. Becker, that the fauna of each horizon be studied in connection with the living fauna.

It seems pretty clear that we have the Miocene well developed and also the Pliocene, but it is not altogether certain that the coal measures are Eocene, for they might very well be later. As Mr. Becker states, sharp lines are difficult to trace in the tropical Tertiary, and it is the writer's opinion that it will be shown in time that in certain localities in the Tropics, principally near sea level, Tertiary conditions, Tertiary fauna and flora may be still existing. Further, the Tertiary as a whole, and its different stages as well, must have been of immensely longer duration in the tropical zone than in boreal regions. We believe that Huxley was nearer right than he is given credit for being in his criticism of the use of the word "contemporaneous." A recent article[1] in a bulletin of the Geological Society of America by Prof. G. F. Williams is interesting, as it bears upon just this point.

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[1] G. F. Williams, *Bull. Geol. Soc. of Am.*, vol. 16, pp. 137–150, March, 1905.

TABLE I.—*Temperatures and rainfall at the Legaspi station.*

Month.	Temperature.			Rainfall.	
	Maximum.	Minimum.	Average.	Millimeters.	Rainy days.
1903.					
May	32.6	22.8	27.7	81.4	15
June	36.2	23.5	29.8	99	6
July	35	21.5	28.2	194	25
August	35.8	21.9	28.8	80.3	9
September	35	31.8	33.4	124.3	19
October	34	21.4	27.7	261.4	17
November	33.9	20.5	27.2	442.8	22
December	([1])	([1])	([1])	([1])	([1])
1904.					
January	30.9	21.5	25.6	799.3	27
February	31.1	17	24.8	544.9	18
March	30.9	23.1	26.7	126.3	9
April	30.9	23.8	26.9	168.8	21
Total				[2]2,222.5	

[1] Missing.

[2] Or 87.5 inches.

TABLE II.—*Analyses of Philippine and foreign coals.*

Locality.	Age.	Moisture.	Fixed carbon.	Volatile combustible.	Sulphur.	Ash.	Specific gravity.	Calorific.	Cost in Manila.
Liguan, Batan Island.	Tertiary	5.62	54.42	38.68	0.14	1.28	1.35		
Do	do	9.53	44.86	41.56	2.37	4.05	1.30	[1]6,983	
Do	do	6.08	51.24	40.36	.40	2.32	1.30	[1]6,487	
Bilbao, Batan Island.	do	12.18	37.96	42.84	1.97	7.02	1.37		
Liguan, Batan Island.	do	5.82	52.40	40.29	.66	1.49	1.58		
Cebu, Caridad Gal	do	9.60	54.56	34.53		1.31	1.31	7,012	
Cebu, Esperanza Gal.	do	7.80	51.96	37.56		2.68		7,461	
Polillo	do	4.7	50.1	43.5	.28	1.7		[1]6,897	
Kishima, Japan	do	2.18	42.60	41.70	2.60	13.70		7,788	[2]$5.38
Yubari, Hokkaido	Cretaceous	1.64	53.10	39.20	.218	4.20			
Miiki Chihuko, Japan.	Tertiary	.70	48.85	42.15	3.34	3.30	1.278		9.00
Japanese (pile at Government ice plant).	do	1.19	56.86	31.22		10.73			
Nanaimo, B. C.[3]	Cretaceous	1.88	54.67	33.27	.78	9.4			
Kootenay, B. C	do	.90	70.99	22.19	.32	5.6			
Pocahontas, Va	Triassic	1	74.39	21	.58	3.03		8,372	[4]5.81
Roslyn, Wash	Tertiary?	2.90	50.60	31.60	.54	14.9			
Nation River, Alaska	Cretaceous or Tertiary.	1.39	55.55	40.02	2.98	3.04			
Drew Mine, Alaska		14.44	33.77	47.15		4.64			
Mulato, Yukon		.86	66.51	25.75		6.88			
Chignik, Alaska		1.89	48.46	41.47	1.91	8.18			
Waikato, New Zealand.		19.82	50.01	29.79		2.20			
Sheridan, Wyo	Cretaceous	6.04	35.57	42.37		16.02			
Deer Creek, Wyo		12.8	47.7	35		3.6			
Sabina Field, Tex	Tertiary	1.37	68.18	16.42		13.02			
Eagle Mine, Tex		3.54	50.69	30.84		14.93			
Danville, Ill	Carboniferous	11	53	32.6		3.6			
Clay County, Ind	do	7	47.30	45		2.50			
El Moro, Colo	Cretaceous	1.32	55.86	38.23		3.59			
John Day River, Oregon.	Tertiary	6.54	52.41	34.45	.65	5.95			
Coos Bay, Oreg	do	15.45	34.95	41.55	2.53	8.05		4,565	
Australia (sold in Manila market).	Permian	2.63	55.67	33.15		8.55		7,630	[2]5.79

[1] Pound calories.

[2] Price to Insular Purchasing Agent.

[3] In use in 1902 in United States quartermaster transport service between San Francisco and Manila.

[4] Price to Naval Department.

TABLE III.—*Analyses of Batan coals.*

Locality.	No.	Moisture.	Fixed carbon.	Volatile combustible.	Sulphur.	Ash.	Color of ash.	Coke.[1]	Specific gravity.
Outcrop, "Big Tree" seam, San Francisco.	1	6.90	40	36.90	0.33	16.20	White		
Do	2a	9.92	49	37.86		3.22	Yellow to grayish white.		
Do	2b	9.40	43.80	38.50	.31	8.30	White		1.368
Interior "Big Tree:"									
8 feet from mouth	3	6.30	46.80	39.40	.53	7.50	do		
East side	4	6.40	46.50	39.70	.45	7.40	do		
Across seam	5	6.50	46	40.60	.60	6.90	do		
San Francisco	7 B. T.	5.80	44.50	41.20	.42	8.50			
Do	8 B. T.	6	44	42.20	.49	7.80			
Drill hole No. 4 A:									
Seam No. 1, Liguan	9	5.74	48.80	39.98	.66	5.70	Yellow	None	1.57
Seam No. 2, Liguan	10	5.82	52.40	40.29	.66	1.49	Orange	do	1.58
Seam No. 3, Liguan	11	5.17	45.91	41.28	.96	7.64	Brown	do	1.64
Seam No. 4, Liguan	12	5.47	44.51	40.23	2.17	9.79	Gray	do	1.53
Seam No. 5, Liguan	13	5.89	45.04	39.68	.97	9.39	Brown	do	1.57
Seam No. 6, Liguan	14	5.83	43.82	40.16	2.69	10.19	Gray	do	1.60
Drill hole No. 11, seam at 66 feet, Liguan.	15	4.53	46.96	45.89	.59	2.62		do	
Drill hole No. 13:									
Seam No. 3, Liguan	16	5.03	47.15	40.82	.45	7		do	1.41
Seam No. 4, Liguan	17	5.10	44.20	45.86	.18	4.84		do	1.40
Seam No. 5, Liguan	18	5.08	50.31	42.03	.25	2.58		do	1.41
Seam No. 6, Liguan	19	5.39	48.28	36.23	.26	10.10		do	1.46
Seam No. 7, Liguan	20	5.38	51.96	39.62	.11	3.04		do	1.37
Drill hole No 11 B:									
Seam No. 1, Liguan	21	5.62	54.42	38.68	.14	1.28		do	1.35
Seam No. 2, Liguan	22	4.88	43.09	45.47	.12	6.56		do	1.47
Batan, Bett's	23	11.09	40.67	44.02	2.36	4.22		do	1.40
Stream Bed, center of island.	24	14.82	37.06	43.28	1.33	4.84		do	1.52
Cross-cut entry No. 4, Liguan.	25	9.53	44.86	41.56	2.37	4.05		do	1.30
Face entry No. 4, Liguan.	26	6.08	51.24	40.36	.40	2.32		do	1.30
Outcrop on Dapdap trail.	2–55	17.56	35.56	42.72	2.23	4.16		do	1.37
Outcrop near Batan trail.	3–55	17.18	38.25	39.08	1.15	5.49		do	1.32
Perseverancia claim	4–55	17.88	34.77	41.32	2.10	6.03		do	1.32
Bilbao	5–55	12.18	37.96	42.84	1.97	7.02		do	1.37
Outcrop in creek near Liguan.	6–55	7.40	48.06	40.84	1.62	3.70		do	1.33
Southeast slope Mount Vizcaya.	7–55	17.22	25.77	51.08	2.16	5.93		do	1.35
On trail from Calanaga to Batan.	8–55	17.77	32.71	45.18	2	4.34		do	1.33
Outcrop near Batan, north.	9–55	18.96	32.79	43.14	2.15	5.11		do	1.30
Outcrop one-half mile northwest of Caracaran.	10–55	9.86	38.89	47.58	2.73	3.67		do	1.29
Southeast corner Cleveland claim.	11–55	11.35	41.01	45.75	2	1.89		do	1.31
Rapurapu	1–65	18.30	35.88	40.44	.38	5.38		do	1.31
Sugot	2–65	15.33	40.45	42.05	1.08	2.17		do	1.36
Calanaga	3–65	17.06	33.59	46.26	1.24	3.09		do	1.32
Bilbao	4–65	5.10	36.31	41.81	1.11	16.78		do	1.34
Calanaga entry No. 3	2–85	20.80	37.30	37	1.13	4.90		do	1.36

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[1] Many of these Liguan coals showed an incipient coking.

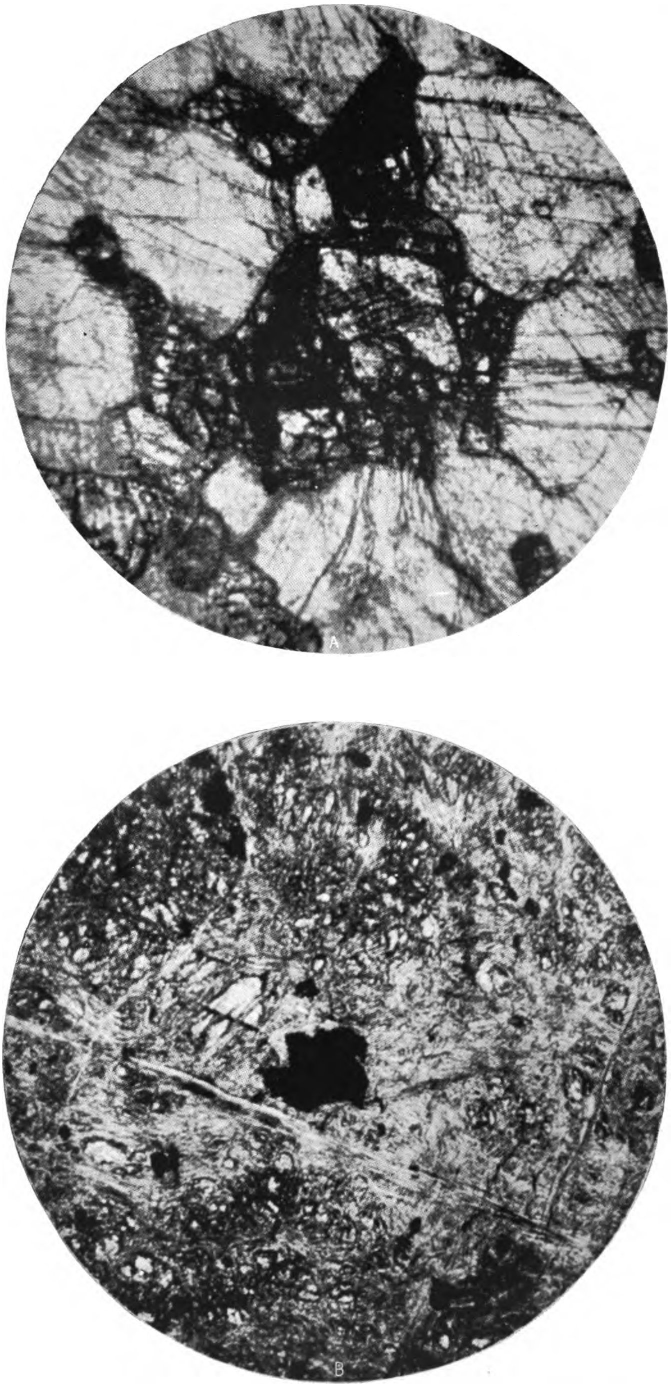
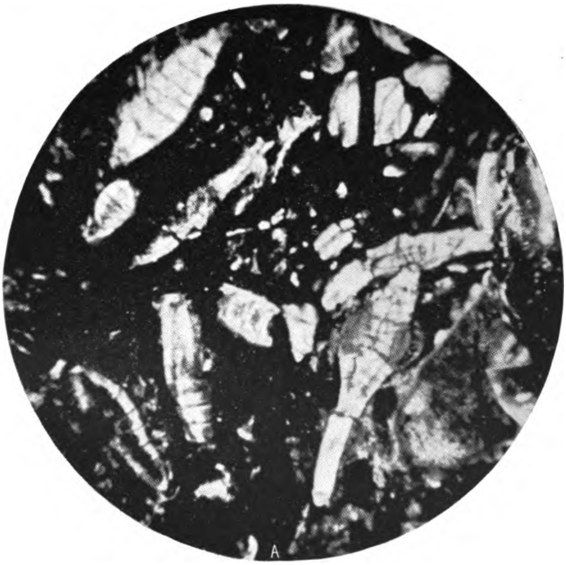


PLATE XIX. (*a*) DIORITE FROM RAPURAPU; (*b*) SERPENTINE FROM BATAN.



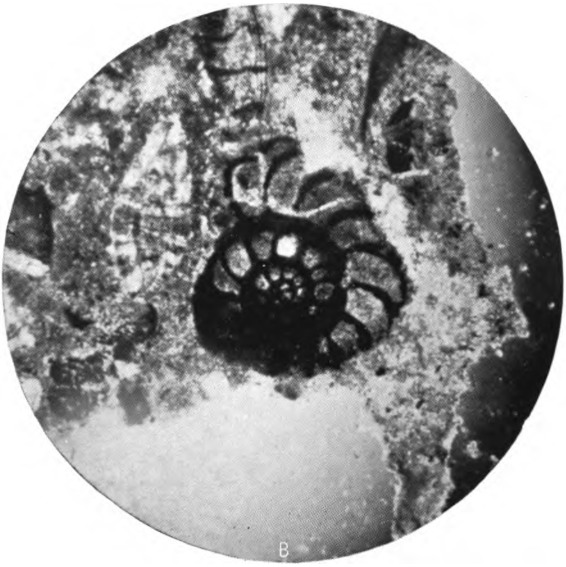


PLATE XX. (*a*) OPERCULINA COMPLANATA; (*b*) AMPHISTEGINA?

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